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# HUMAN PERFORMANCE RELIABILITY IN COMMAND AND CONTROL SYSTEMS: THE NAVAL TACTICAL DATA SYSTEM (U)

WILLIAM HARRIS
GERALD L. MOE



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# HUMAN PERFORMANCE RELIABILITY IN COMMAND AND CONTROL SYSTEMS: THE NAVAL TACTICAL DATA SYSTEM (U)

## INTRODUCTION

(U) The study of human performance reliability in any real-life situation must meet at least one basic requirement: the existence of operational performance data. If performance data are not taken from operational situations, it may matter little that one has a scheme to "model" performance reliability. The techniques and tools are available to construct human reliability models; how useful a given model will be in predicting human performance in a given situation will depend largely on the availability of relevant data to implement the model. Swain (1969), in an overview of the status of human factors reliability analysis, concluded the primary need is for a "central bank" of human performance data.

> Several years ago, we had reached the point where our mathematics and reliability technology had far outstripped the available human performance data. Today, if anything, the gap has widened.

(U) There had been an attempt to establish a central data bank of human performance reliability (the AIR data store, e.g., Altman, 1964). But the performance data in the bank was derived mainly from laboratory studies, not from operational performance situations. The level of task description was in terms of task *elements*, such as the time required to engage a toggle switch and the probability of a correct response, or the time and probability of correctly reading a numeral of given dimensions. The data in the bank, then, were times and probabilities associated with very small units of performance. The performance of any reasonably complex operational task would comprise a great many such units. A major problem concerns how to combine these units to come up

with some measure of *task* reliability, rather than of task *element* reliabilities.

(U) The main requirements for a useful human performance data bank are that the data be collected under operational conditions, that the conditions be clearly specified, that the level of task description be "appropriate," and that the user of the bank be taken into account. "Operational conditions" covers a wide range of variables that affect human performance, from the characteristics of performers to the performance environment. A practical operational performance data bank cannot reflect *all* the conditions of performance, but the *significant* conditions must be represented. An "appropriate" level of task description is likely a level of organization considerably higher than task elements. The probable user of an operational data bank is the system designer. If the bank is to be useful to him, the data must be in terms that he can understand and apply at the various stages of system evaluation. The "search" terms of the bank, probably terms that refer to system functions, at the highest level of term organization, should enable him to retrieve relevant data quickly.

*Study Objectives*

(U) The main purpose of this study was to determine the requirements for the development of an operatienal data bank of human performance in command-and-control systems. To achieve this purpose it was necessary to conduct a detailed analysis of a specific command-and-control system.

(C) The system selected for analysis was the Naval Tactical Data System (NTDS). This is a highly automated, computerized system in wide use in the Navy. It is likely that future systems will follow the NTDS model, rather than earlier, less automated system models. The NTDS surely contains all the elements of command-and-control systems: allocating and keeping

track of forces, detecting and keeping track of targets, identifying targets, deciding what to do about them, selecting appropriate actions, and taking the actions. In short, the NTDS is a highly sophisticated information processing system.

(U) Staff members of the Human Factors Division of the Naval Electronics Laboratory Center (NELC) participated in this study. Their major contributions were in the development of an automatic recording system (called the Data Recording System) and in cooperation in the design and execution of the study.

(U) The specific objectives of the study were as follows:

1. Develop a functional system description, particularly of man-man and man-machine interactions.

2. Develop detailed task descriptions of selected tasks.

3. Evaluate operational data collection methods.

   a. Direct recording of system events.

   b. Observations of system events.

   c. Judgments of operator performance.

4. Identify system performance criteria.

5. Identify the variables that affect system performance.

6. Develop a taxonomy of task performance and an error classification scheme.

7. Determine the characteristics of an operational data bank.

8. Develop a plan for continued research.

*Study Activities*

(U) The main activities of the study are described briefly in the following paragraphs. The outcomes of these activities

are described in following sections of the report.

*Information Sources*

(U) *NTDS Documentation.* The NTDS Input and User Operator Manuals were reviewed and analyzed in detail. These manuals contain brief general descriptions of each NTDS operator task. In addition, they provided a functional description of the NTDS consoles in each mode of operation. See the references for a list of other NTDS documents reviewed during the study.

(C) *Observations.* Project personnel spent more than seven man-weeks visiting FAAWTC San Diego and NTDS-equipped ships in the Southern California area during the course of the study. A part of nearly every day was spent observing NTDS operations, witnessing demonstrations, or operating NTDS equipment. Project personnel visited the USS GRIDLEY (DLG 21), USS JOUETT (DLG 29), USS HORNE (DLG 30), and the USS FOX (DLG 33). In addition, one member of the project staff spent a week on board the USS STERET (DLG 31). This latter experience was particularly useful in illustrating the difference between classroom or textbook NTDS and the reality of shipboard NTDS operations.

(C) *Interviews.* Numerous interviews were conducted with NTDS instructors and operational personnel. In fact, many more interviews were conducted than had been anticipated due largely to the inadequacy of the NTDS operator manuals. The purpose of these interviews was to supplement the information in the Operator Manuals, identify training and operational problems, and to establish working relationships with key NTDS personnel at FAAWTC, COMCRUDESPAC, and NELC.

(U) At FAAWTC, San Diego, instructors specialize in teaching one or more of various modes of NTDS console operation. Usually two or more instructors are assigned to teach each console mode. Interviews were conducted with one or more instructors

assigned to each console mode. A part of every such interview was a discussion of the problems each operator has in interfacing with the system and with the other console operators.

(U) Similarly, interviews were conducted with each type of operator aboard ship.

(C) One of the more interesting aspects of each of these interviews was a discussion of performance standards. No one was aware that there were any standards, but everyone had an opinion of what standards should be, and there was a great deal of variability in the opinions expressed.

(C) *HFR Projects.* Of the ongoing HFR projects that relate to this study, one is of particular interest. This project, sponsored by ARPA, is concerned with developing procedures for allocating functions between men and machines in future generations of automated surveillance systems. Considerable effort has been expended during this study to develop system and operator task descriptions, develop a task taxonomy, and identify performance parameters and criteria.

(U) The similarities and differences between the ARPA study and this one have perhaps provided a clearer insight into both projects.

(U) *General Literature.* The general literature on human performance reliability and the development of task taxonomies was reviewed. A particularly useful reference has been Miller's (1971) study of a taxonomy of human performance.

*Analytical*

(C) *Functional System Description.* The development of a functional description of the NTDS was fairly straightforward. At the level of overall system objectives it is fairly simple to *infer* these objectives from the material presented in the system manuals. It would seem, however, that a publication that described the system objectives and which discussed in

some detail the differences between NTDS systems would be useful not only to researchers but to operational commanders and training commands as well.

(C) *Functional Task Descriptions.* Many difficulties were encountered in developing task descriptions. The operator's tasks are simply not described very well in the operator manuals. At no place in the operator manuals are procedures described. Consequently, it was necessary to spend considerable time in discussions with NTDS personnel to arrive at an adequate description of any operator's task.

(U) *Identification of Relevant Variables.* Both performance and situational variables were identified. The assistance of fleet and training personnel was sought in the identification of variables. An attempt was made to obtain an estimate of the perceived importance to operator performance of the variables identified, and to identify those variables applicable to all operators, and those associated with only particular operators.

(C) *FAAWTC San Diego Curriculum and Performance Tests.* The entire NTDS curriculum used at FAAWTC San Diego was reviewed and analyzed. The performance tests used were also analyzed. The curriculum objectives and performance tests do not include system-related performance criteria. Initially this was thought to be a deficiency in the curriculum and performance tests. Later it was learned that the deficiency, though a real one and recognized as such by NTDS instructors, does not reflect the competence of instruction but rather reflects the non-existence of NTDS performance standards.

*Developmental*

(C) *Judgmental Data Collection Method.* The first task in the development of a judgmental data collection method was to identify the most frequent/important errors made by NTDS operators.

The original intention was to develop an exhaustive list of errors for each operator. With such lists in hand, it would have been possible to not only identify the relative importance of these errors for individual operators but to also analyze errors across operators. This plan was quickly abandoned when it was learned that identifying operator errors would be far more difficult than had been anticipated. The initial error identification effort had, however, served to focus our attention on the Track Supervisor (TRK/SUP) task as perhaps the most difficult NTDS task.

(C) The TRK SUP is the "man-in-the middle" in NTDS operations. He interfaces with every other member of own-ship's NTDS team and his performance affects the performance of every other operator. Consequently, the details of the TRK SUP task are relatively well known to all NTDS operators. Therefore, it seemed reasonable to expect any NTDS operator to be able to judge the importance and frequency of TRK SUP errors.

(C) Some 50 errors were identified, from sources available at the time, that the TRK SUP might make in performing his several tasks. Through interviews and pilot tests among FAAWTC instructor and shipboard personnel, the list of errors was reduced to 20 that were judged to be important and to occur relatively frequently. Judgments were obtained from operational personnel on two NTDS ships, using a ranking method, about the relative importance and frequency of occurrence of the 20 errors under different tactical conditions.

(U) *Data Reduction Logic.* NELC has developed the Data Recording System (DRS). Briefly, the system is capable of recording, in real time, events in the NTDS that result in an electronic signal, such as button pushing responses, track number designators, and x-y positions of tracks. Thus, the output of the DRS is a record of the identification of an event and the time of its occurrence. The record will be

computer processed, so some guidelines were needed for computer programs.

(C) HFR contributed in the development of the logic required for the design of data reduction programs. In some instances, the interest is in the time between successive events: for example, the time between a Firm Track entry and an identification response entry directly gives the time required to make an identification response. The reduced data required are distribution statistics, perhaps the mean and variance of response times. In other cases, the interest is in the sequence of button pushing responses: for example, a Drop Track response immediately following a gridlock correction sequence of responses may indicate an invalid track has been in the system. The reduced data required is the frequency of occurrence of such events and performance times associated with them. The data reduction logic required to interpret DRS recordings is often complex and involves a consideration of the significance of given events in relation to others.

(U) Observers will be required to collect operational data that cannot be directly recorded, such as operator overt behavior in performing given tasks, the characteristics of operators, communications between operators, and the presence of variables that may affect performance. There is a requirement for reduced data; for example, the scaling of operator behavior measures.

(U) Some events cannot be directly recorded or observed, particularly the decision-making processes in an operator that occur between overt responses. The reduced data requirement may be for the scaling of decision task difficulty measures.

(U) *Task Taxonomy Development.* A preliminary task taxonomy has been developed that seems to be applicable to the NTDS and to command-and-control systems in general. Error classification schemes also have been considered.

(U) *Characteristics of an Operational Data Bank.* The total activity of this study has been directed toward developing the characteristics of an operational data bank. The data collection methods, the form of reduced data, the identification of relevant variables, the level of task descriptions, all bear on the characteristics of the bank. Some likely characteristics, taking the user into account, have been identified.

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# DESCRIPTION OF THE NAVAL TACTICAL DATA SYSTEM

(U) The description of the Naval Tactical Data System (NTDS) given below is by no means a complete and detailed one. It is a description of selected elements--selected to provide the reader with an overall view of the system and some understanding of its complexity.

*General Description*

(C) NTDS is a computer-controlled multi-purpose command-and-control system. The system capabilities include automated tactical data collection, processing, displaying, and reporting--the system collects, processes, and displays real-time information required by command for tactical decision making. NTDS correlates sensor and communications information to perform such functions as target detection, location, tracking, course and speed computation, identification, and determination of the number of attacking units. (3)

(C) NTDS information is displayed automatically on a number of operator consoles in the Combat Information Center (CIC). Command personnel monitor the tactical situation and issue necessary orders. Automated display of real-time tactical data is intended to enable command personnel to grasp the tactical situation quickly and accurately with little effort, thus permitting them to concentrate on effective weapons direction and force allocation. (3)

(C) When more than one NTDS ship is operating with a task group, the computers of the NTDS Participating Units (PUs) are linked together by a communications circuit known as Link 11. PUs exchange real-time NTDS track data and symbology via Link 11 (raw radar video is not exchanged among PUs). Non-NTDS ships in the task group participate by making voice radio reports of own-ship targets and by receiving situation reports via a one-way teletype link (Link 14).

(C) There are some differences between NTDS systems depending

on the class of ship on which they are installed. For example, large ships, CVAs and cruisers may have three or four general-purpose computers, whereas smaller ships, DLGs, have but two computers. Generally speaking, the additional computer on the large ships provides the necessary computer facility required for *air traffic control* and for increased ECM capability. There are programming differences existing between ships serviced by Fleet Computer Programming Center, Pacific, and those serviced by Fleet Computer Programming Center, Atlantic. These programming differences relate more directly to the management of computer capacity than they do to the actual operation of the system.

(C) Another difference among ship types is in the number of NTDS consoles installed. Larger ships have as many as 30 consoles, whereas smaller ships have as few as 10 consoles. On large ships, particularly CVAs, the "extra" consoles are used in non-combat operations, primarily for air traffic management and control.

(C) On each ship, the consoles are divided between User and Input functions. The User consoles are operated by personnel with tactical decision-making responsibility. The Input consoles are operated by lower echelon personnel who are not directly involved in *tactical* decision making.

(C) Table 1 identifies the NTDS User and Input consoles and operator functions; those functions indicated by asterisks were analyzed in detail for the purposes of this study.

TABLE 1

NTDS CONSOLES AND OPERATOR FUNCTIONS

| Users | Input Operators |
|---|---|
| 1. Flag | 1. Air Detector/Tracker* |
| 2. Force Weapons Coordinator* | 2. Height Size |
| 3. Ship's Weapons Coordinator* | 3. Identification* |

TABLE 1

NTDS CONSOLES AND OPERATOR FUNCTIONS
(Continued)

| Users | Input Operators |
|---|---|
| 4. Intercept Controller* | 4. SIF Tracker |
| 5. Air Traffic Controller | 5. Track Supervisor* |
| 6. Command Mode | 6. ECM Supervisor |
| | 7. Surface Tracker |
| | 8. Air Operations Tracker |

*Console Description*

(C) Each console is a multi-mode console; that is, any of several modes of operation can be selected at a particular console by selector switch action. Although NTDS consoles can be operated in different modes it is customary aboard ship for particular consoles to be used in only one mode, unless equipment casualties or other unforeseen events occur. Moreover, the consoles are grouped together by function--the Input consoles are located in one area, and the User consoles in another area usually several feet away.

(C) There have been four generations of NTDS consoles: SYA-1, SYA-4, UYA-1, and UYA-4. The UYA-4 consoles are universal consoles, that is, any User or Input mode can be selected on any console. In the previous models there were two types of consoles, one for Users and another for Input Operators.

(C) All four generations of NTDS consoles are presently in use in the fleet. In their appearance and functional characteristics the various models are quite similar. However, there are numerous detailed differences between consoles particularly between the UYA-4 and the first three models. These differences are sufficient to warrant a period of retraining or reindoctrination if a man is transferred from a ship with one type of console to a ship with a different type.

(The NELC Data Recording System, described in a later section, is compatible with any model of NTDS console. This can provide the opportunity to compare performance on different consoles.)

(C) Figure 1 shows the configuration of the UYA-4 Universal Display Console. The main displays and controls are identified below.

*Visual Displays*

(C) *The PPI and Scope Symbology.* The principal NTDS display is a standard 12-inch PPI. In addition to raw radar video, NTDS symbology is displayed on the PPI (see Appendix C for a listing of NTDS symbology). The symbology is of three types: track symbols, engagement symbology, and special points and lines. The shape of the track symbols indicate whether a track is an air, surface, or subsurface contact and whether the track has been identified as friend, hostile, or unknown. Engagement symbology is used to indicate the engagement status of each target and force weapon. A Pairing Line is used to indicate which weapon is assigned to which target. Special points and lines are used to display information of tactical interest not directly associated with the location and movement of friendly or hostile forces, such as clutter points, approach corridors and missile envelopes.

(C) *Data Readout (DRO).* The DRO is used to display amplifying data concerning the track in close control. There is a standard DRO display associated with each console mode. The information displayed in the standard format is that required most often by a particular operator. For example, the standard Ship's Weapons Coordinator DRO displays engagement status information and the standard Track Supervisor DRO format displays track status information. Each operator, by Function Code entry, can call up a variety of DRO formats that provide additional amplifying information.

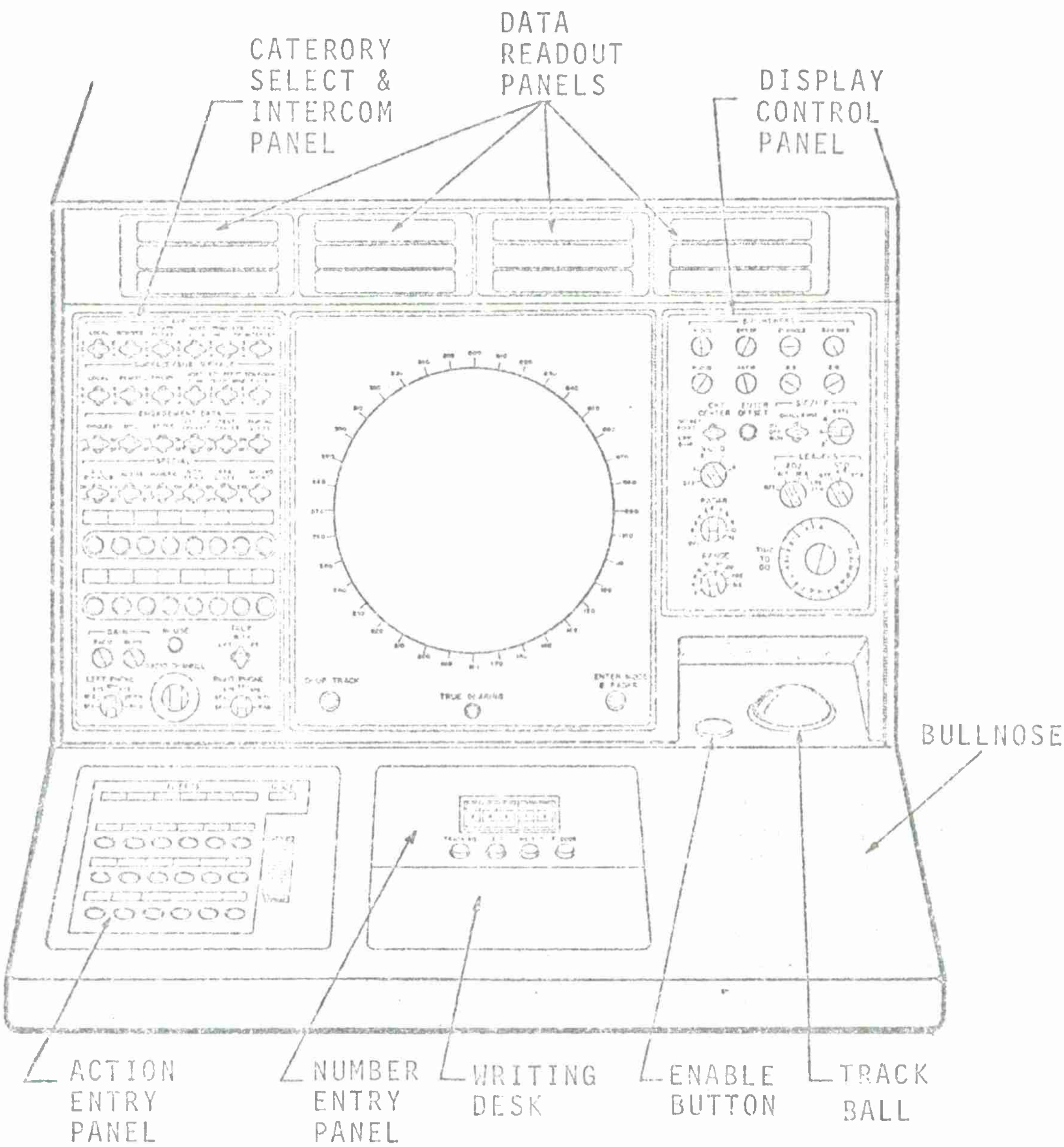


Figure 1. Configuration of the UYA-4 Console.

(C) *Identification of Controls.* Most of the console knobs, switches, and buttons perform fixed functions and have permanent labels. The function of Quick Action Buttons (QAB) is dependent on console mode. The QAB labels change when the console mode of operation is changed.

(C) *Mode Identification.* The mode of operation selected at a console is displayed to the operator by a back-lighted indicator. The lettering displayed on the indicator changes with each change of mode.

(C) *Function Code Identification.* Function Codes are entered using number entry dials or buttons. The numbers entered are displayed to the operator so that he can verify whether they are the ones he intended to enter. A list of General Purpose Function Codes is usually taped to the bullnose of each console.

(C) *Alert Panel.* The Alert Panel consists of a row of six lights. Alerts are used to inform the operator of special situations that usually require his immediate attention. Whenever an operator performs an action which the computer will not accept, he receives an Illegal Action alert. The alerts indicated by the other five lights on the Alert Panel vary as a function of console mode.

*Auditory Displays*

(C) *Radio Telephone.* The Force Weapons Coordinator (FWC), Ship Weapons Coordinator (SWC), Track Supervisor (TRK SUP), Intercept Controller (IC), and the Identification Operator (ID) communicate with other units via voice radio.

(C) *Sound-Powered Phone (S/P).* All members of the NTDS CIC team are linked together via S/P phones. The communications panel located on the NTDS console is used to call up particular operators. A pointer symbol associated with this panel can be used by one operator to indicate position on the PPI to another operator. The pointer symbol is controlled

by the Track Ball.

(C) *Buzzer Signal.* Whenever an operator receives an alert a buzzer sounds to draw his attention to the alert. The buzzer is silenced when the operator pushes his Alert Review button.

*Controls*

(C) *PPI Display Adjustment Controls.* Each NTDS console is equipped with controls used to adjust the display of raw radar video on the PPI: focus, brightness, astigmatism, and so on.

(C) *Category Select Panel.* The Category Select Panel is used to control the display of scope symbology. The operator can elect to have all symbols displayed or deleted, to have certain symbols blink under specified conditions, or to have the form of symbols changed; for example, all remote or friendly tracks may be displayed as dots rather than as standard symbols. The purpose of the Category Select function is to reduce scope clutter while retaining all the information needed by a particular operator to perform his task.

(C) *Quick Action Buttons (QABs).* QABs are used by the operator for rapid communication with the computer. QABs are of two types: fixed and variable function. The QABs available at each console vary as a function of console mode selection. The following is a list of QABs available to the operators of primary interest in this study.

*Force Weapons Coordinator (FWC)*

1. Alert Review
2. Break Engage
3. Cease Fire
4. Engage Interceptor
5. Engage Missile

6. Position Correction

7. Range and Bearing

8. Track Review

*Ship Weapons Coordinator (SWC)*

1. Alert Review

2. Break Engage

3. Cease Fire

4. Engage Interceptor

5. Engage Missile

6. Position Correction

7. Range and Bearing

8. Track Review

*Intercept Controller (IC)*

1. Accept Engagement Assignment

2. Cannot Engage

3. Collision Intercept Trial Geometry, Request for

4. Data Readout

5. Down/Left, Up/Right (these are dual function QABs; they are used to order speed decreases/increases or port/starboard turns)

6. Fuel on Board Interceptor

7. Order Sent

8. Position Correction

9. Pursuit Intercept Trial Geometry, Request for

10. Range/Magnetic Bearing (this QAB is used to request a readout of the target bearing and range in relation to the interceptor)

11. Reposition

12. Sequence

13. Steady

14. Speed Magnetic Heading

*Track Supervisor (TRK SUP)*

1. Automatic History Display

2. Automatic Offset

3. Course and Speed

4. Display Accept Remote

5. Interchange

6. Late Detect

7. New Track

8. Non-NTDS

9. Position Correction

10. Navigation Position Data

11. Range and Bearing

12. Split

13. Track History

14. x-y coordinates

*Identification Operator (ID)*

1. Airborne Early Warning Aircraft

2. Air

3. Assumed Friend

4. Assumed Hostile

5. ASW Aircraft

6. Friend

7. Helo

8. Hostile

9. Interceptor

10. Reference Point

11. Sequence

12. Strike Aircraft

13. Surface

14. Track History

15. Unknown

*Detector/Tracker (DET/TRK)*

1. Automatic Track History

2. Automatic Offset

3. Assign Here

4. Late Detect

5. New Track

6. Position Correction

7. Sequence

8. Split

(C) In addition to the QABs listed above, each operator has fixed function QABs such as Drop Track, Function Code entry, and Enable Ball Tab.

(C) The only manual task performed by NTDS console operators that is not a button pushing or switching action is the positioning of the Ball Tab, which is done by rolling the Track Ball.

*Task Descriptions*

(U) General task descriptions for the six major NTDS functions are given below. Detailed task descriptions are presented in Appendix B.

(C) *Force Weapons Coordinator (FWC)*. The FWC acts for the Officer in Tactical Command (OTC) and is responsible to him for evaluation of the force tactical situation, and for the combat direction of force weapons. The FWC is responsible for continuously reviewing and reevaluating the tactical situation and ordered engagements for making changes in engagement assignments as necessary. In contrast to conventional (non-NTDS) task groups where the OTC usually delegates the duty of Force AAW Commander to a subordinate commander, the NTDS OTC usually exercises this responsibility himself (through a senior member of his staff acting as FWC).

(C) *Ship Weapons Coordinator (SWC)*. The SWC is responsible for the combat direction of own-ship's weapons. SWC directs engagements of own-ship's weapons either in response to the Force Weapons Coordinator's orders or on his own initiative.

(C) *Intercept Controller (IC)*. The IC's primary responsibility is to control aircraft on intercept and other type missions. Usually the IC acts in response to SWC orders but may act on his own initiative to counter an immediate threat.

(C) *Track Supervisor (TRK SUP)*. The Track Supervisor monitors and supervises the performance of all own-ship Input operators. In addition, he is responsible for maintaining gridlock, monitoring the performance of Link 11 and 14, and acting as the Combat Information and Detection (CID) Net communicator. He also acts as a back-up for all other input operators.

(C) *Identification Operator (ID)*. The ID operator is responsible for performing that portion of the identification task delegated to him by command and for entering the identification of all tracks into the system. The identification of a given track is determined on the basis of (1) Identification Friend or Foe/Selected Identification Feature (IFF/SIF) information, (2) the track's course, speed, and altitude,

(3) intelligence data, (4) the target's responses to ordered maneuvers, (5) current operation orders, and (6) orders received from the Officer in Tactical Command (OTC).

(C) *Detector/Tracker (DET/TRK).* The primary responsibilities of the DET/TRK are to detect targets, enter new tracks into the system, and to then maintain an accurate track on each track in his assigned sector of responsibility.

(C) The tasks required of the NTDS operators perhaps can be better appreciated by considering the sequence of events that occur with respect to a single hostile track that enters the system. Figure 2 shows a kind of operational sequence diagram of the operator actions from the search for and detection of a target to the final event of its destruction. The situation depicted is greatly simplified, because there are usually many other tracks in the system at given times. The events occur in the time order suggested by the placing of the boxes from top to bottom of the diagram, though no times are given. The total time available from track entry to exit depends on such factors as the range a target is detected, its course and speed, and its weapon release point. The diagram is described in detail on the pages following Figure 2.

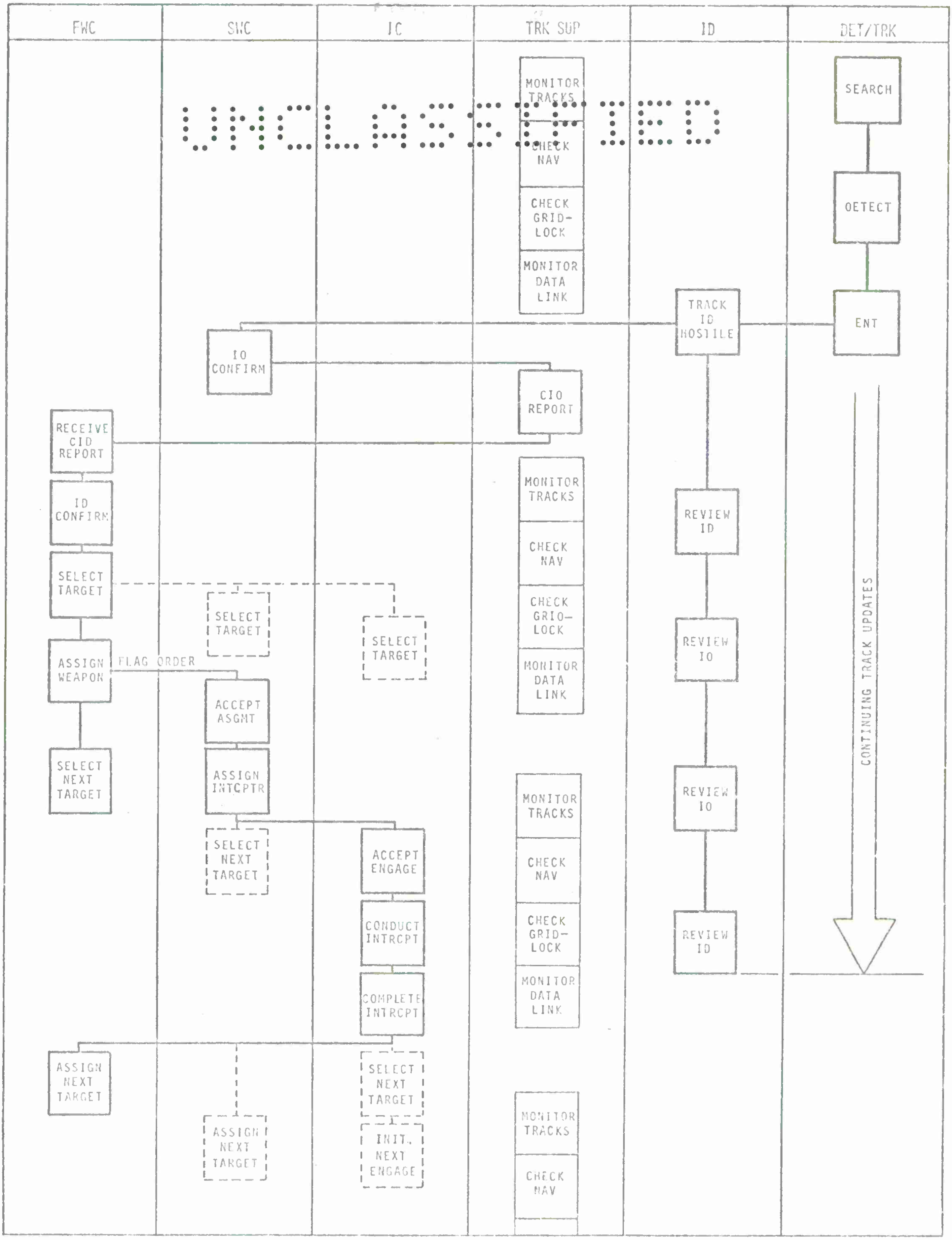


Figure 2. Diagram of NTDS Operator Actions

## *Description of the Diagram of NTDS Operator Actions*

### *Search*

(C) The diagram depicts Search as a single action by a single operator. In reality, search is a continuing activity engaged in by *every* console operator. It is important to note that as the overall level of activity increases there is a consequent decrease in both the time available for search and the effort devoted to it.

(C) NTDS has a Detector mode of operation. Originally one or more console operators were assigned to this mode and assigned the single task of search. Over the years, operational experience has led fleet users to the conclusion that it is not necessary to have consoles/operators devoted exclusively to the search task. The standard operating procedure is now to combine the roles of Detector and Tracker (DET/TRK).

### *Detect*

(C) Each operator may see the same radar presentation.* Therefore, any operator may be the first to detect a new piece of video. New tracks are normally entered by Input operators, usually the TRK SUP or the DET/TRK, but Users in the Utility Mode may also enter new tracks.

### *Enter New Track (ENT)*

(C) As used here, ENT includes several individual actions. New tracks are entered into the system in the following manner. When an operator detects a new piece of video, he enables his Ball Tab, rolls it to the position of the video, aligns the

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*NTDS ships have more than one air-search radar plus a surface-search radar. Moreover, the DET/TRKs (usually two or more) typically have their radar display offset to effect search sectors. It is, however, true that any operator *can see* the same radar presentation.

Ball Tab with the center leading edge of the video, and presses the New Track Quick Action Button (QAB). At this point a tentative track symbol appears on each Input operator's PPI display (but not on the User consoles). When the track has been updated, Position Corrected, three times, it becomes a firm track. Firm tracks symbology is displayed on all ownship's consoles and is transmitted to other NTDS ships via Link 11. A track number is automatically assigned to each new track by the computer.

(C) If 72 seconds elapse between updates *before* a track becomes a firm track, it is *automatically dropped* by the system. If 72 seconds elapse between updates after a track becomes a firm track, it becomes a trouble track. Trouble tracks are indicated by blinking scope symbols. This blinking feature alerts the operator(s) that the track has not been updated for some time (72 or more seconds) and that it should be updated *as soon as possible*. Trouble tracks do not, however, receive any special sequencing priority.

(C) The NTDS tracking task differs from normal radar tracking in that it is not necessary to locate the track manually (after the track is entered initially). The series of events in the tracking task are as follows: the DET/TRK presses his Sequence QAB; this places a track symbol in close control, the Hook symbol appears around the track symbol; the DET/TRK checks the alignment (displacement if any) of the symbol dot (e.g., ^) with the center leading edge of the video. If the dot is superimposed on the center leading edge of the video, the DET/TRK presses his Position Correction QAB. The Position Correction action enters the update and causes automatic sequencing to take place. If the symbol dot is not superimposed with the center leading edge of the video, the DET/TRK presses the Ball Tab Enable QAB. This causes the Ball Tab symbol to appear in the center of the Hook symbol. The DET/TRK then uses his Track Ball to roll the Ball Tab to the center leading

edge of the video. He then presses his Position Correction QAB which causes the track's present position, the position of the video, to be entered into the system. Notice that whether or not it is necessary to correct the position of the track, the Position Correction QAB is used to enter the track's present position to update the track.

*Identification*

(C) The identification procedure for known friendly aircraft is straightforward. The ID operator places a track in close control; this can be accomplished either automatically or manually. He enters the General Purpose Function Code (GPFC) for IFF interrogate, then presses the Function Code button. This causes the IFF equipment to interrogate an area centered on the position of the Hook symbol; that is to interrogate the track in close control. The IFF return is displayed on the UPA-50 IFF display panel. The code displayed on the UPA-50 will be the aircraft's PIF (Personal Identification Feature) code and will specifically identify its parent carrier, squadron, and side number. The ID operator compares this number with a list of PIF codes for the friendly aircraft known to be operating in the area. He then enters the PIF code in his number entry dials and presses his Selected Identification Feature (SIF) QAB. Then, using the appropriate QABs, he enters the track's *Class* (in this case, "air"); its *Category* (e.g., interceptor AEW, helo); and its *Identification* (in this case, "confirmed friend"). This identification information becomes associated with the track and is displayed on every operator's PPI in the form of track symbols; for example, '/.\' for 'air hostile,' '⌈.⌉' for 'air unknown,' '⌒.' for 'air friendly.' Amplifying identification information can be called up for display on the DRO.

(C) The identification of tracks other than those known to be friendly is somewhat more involved. Identification friend

or foe is a command function. The Commanding Officer delegates to his subordinates the authority to identify certain kinds of tracks, generally tracks that are confirmed friend, assumed friend, or unknown. He does not, usually, delegate authority to identify tracks as assumed or confirmed hostile.

(C) When the CO is immediately available, as he would be during General Quarters, his retention of the authority to identify tracks as hostile creates little if any difficulty or delay. When the CO is not immediately available, such as when he is asleep during routine night steaming, failure to delegate authority to identify tracks can create problems. To partially compensate for the potential delay inherent in this situation, each ship has an ID SOP (Identification Standard Operating Procedure) which establishes guidelines to be used when the CO is not immediately available.

(C) If the ID operator is unable to identify a track using SIF/IFF procedures described earlier, he informs the SWC and TRK SUP. The ID operator has several options available to him. He may check the flight schedule to determine whether a friendly aircraft is supposed to be where the aircraft in question is, or whether the aircraft in question is flying at the predesignated course, speed, and altitude given in the flight schedule. He can request the Electronic Countermeasures (ECM) Supervisor to attempt to identify the track. He may attempt to establish voice communications with the aircraft. If he is successful in establishing communications, the ID operator will inform the pilot that his IFF equipment is not operating. If the pilot turns on his IFF gear, the identification procedure reverts to the routine SIF/IFF procedure described earlier.

(C) If the IFF equipment does not come on, the ID operator may ask the pilot to perform a prearranged ordered maneuver

(a sequential pattern of turns). Or he may elect to conduct a visual check of the unidentified aircraft; that is, have a CAP aircraft intercept the unidentified aircraft. Or the ID operator may elect to lock-on the unidentified aircraft with own-ship's fire control radar.

(C) It is important to note that the ID operator does not have the authority to initiate any of the latter three procedures on his own. Before proceeding with any of them, he will have to obtain permission to do so from the SWC, who may in turn have to obtain permission from the CIC Evaluator (the senior officer on watch in CIC) who may have to obtain permission from the CO.

(C) Either the SWC, the Evaluator, or the CO may have information of an intelligence nature that is not available to the lower echelons of the command structure.

(C) Assuming that any or all of these procedures are initiated, any result of other than confirmed or assumed friend or unknown may still have to be cleared with the command structure before it is entered into the system and thus transmitted over the data link.

(C) Once the ID is transmitted over the data link, the Task Group Commander, actually the Force Weapons Coordinator (FWC), and the Force ID Operator, will repeat some or all of the above procedures and either confirm or deny own-ship's ID.

(C) If the FWC/Force ID Operator or another ship disagrees with own-ship's ID, an ID Conflict is said to exist. ID conflicts are resolved automatically by the computer in favor of the most positive information; for example, if one ship reports assumed friend and another confirmed friend, the system accepts confirmed friend. If the system cannot resolve the conflict, it is resolved manually by the two

ships involved. If they cannot resolve the conflict, the FWC acting through the Force ID Operator can resolve the conflict unconditionally.

(C) The length of time available to identify a track depends on the tactical situation. The "required certainty before action" will also vary with the tactical situation. It would seem apparent that the longest delays and the greatest "required certainty before action" would occur at night during routine situations, the very time when the threat of surprise attack is probably greatest, and, therefore, the necessity for quick response is also greatest.

(C) The ID operator task is not completed when he assigns an initial ID to a track. The ID of each track is reviewed aperiodically for as long as it remains within radar range of own-ship, or in the case of a hostile until weapons are fired. Ideally the ID of a hostile would be reviewed just prior to each of the following actions: Target Selection, Accept Assignment, Accept Engagement, and Completion of Intercept.

*IDentification Confirm*

(C) The SWC, Force ID operator, and the FWC will check the identification of each track to either confirm or deny the ID entered by the ID operator. The check by each of these operators will consist of looking for obvious errors or of applying additional information not available to the other operators. The ID Confirmation check will be repeated aperiodically and for hostile tracks up to the moment of firing a weapon.

*Combat Information and Detection (CID) Net Report*

(C) The TRK SUP reports to the FWC, using the Combat Information and Detection (CID) voice radio reporting circuit, the initial track data for each track that is not identified as

a Confirmed Friend. Since the FWC will already have received this information via the data link, this report is simply an alerting and confirming message.

*Select Target*

(C) Target selection may be accomplished either at the force level or at the own-ship level. The FWC is primarily concerned with the defense of the force as a whole, whereas the SWC is primarily concerned with the defense of his own-ship. The objective of the FWC and the SWC(s) is to engage and destroy as many enemy aircraft as expeditiously as possible and as far as possible from the Vital Area (the position of the protected force). A corollary objective is to minimize the length of time a particular weapons system (interceptor or missile) is engaged with a particular target.

(C) Targets are selected on the basis of their threat to the force or to own-ship. Threat value is based on the target's ID and its range, course, speed, and altitude. The system computes a threat number for all system tracks except for those identified as Confirmed Friend. An emergency track alert is generated and presented to FWC and SWC whenever a track threat number reaches a predetermined level. The SWC or the FWC can ignore this track temporarily (by sequencing away from it), but the alert will be regenerated each time the threat number increments.

(C) The FWC or SWC select targets by reviewing their PPI and DRO presentations. They can Sequence to all system tracks or to all system air tracks as they choose (the choice is effected by a GPFC action). As each track is placed in close control, the tracks' characteristics are displayed in the DRO.

*Assign Weapon*

(C) Weapon selection is also the responsibility of the FWC or the SWC. The weapon selection strategy is based on the

theory of defense in depth. For example, assume that the weapons available consist of long- and short-range interceptors (as used here, range refers to the initial position of the interceptors, not to their tactical characteristics) and long- and short-range SAMs (in this instance range does refer to the missile characteristics but may also refer to the position of the missile ship). The preferred weapon is the weapon that can engage the target at the greatest distance from the force or own-ship. Thus the long-range interceptor would be the first choice, the short-range interceptor the second choice, and so on. This scheme has the advantage of not only engaging targets at the greatest distance possible, but also of providing successive lines of defense in case the enemy is not destroyed by the preceding line of defense.

(C) The FWC makes a weapon assignment by Hooking the target and Ball Tabbing either the interceptor or the ship designated to conduct the intercept and then pressing his Engage Interceptor QAB. This action causes a pairing line to be drawn on the FWC's PPI between the target and the interceptor and to be transmitted over the data link. This action also generates a Flag Order Alert at the SWC console of the ship controlling the designated interceptor.

(C) The procedures followed by the FWC when he selects a missile are essentially the same as when he selects an interceptor. The FWC Hooks the target, Ball Tabs the missile ship, and presses his Engage Missile QAB. Again a pairing line is drawn on his scope and transmitted over the data link, along with a Flag Order Alert.

*Accept Assignment*

(C) A buzzer sounds to inform the SWC that he has received a Flag Order Alert. The Flag Order Alert light on his Alert Panel also lights up. He presses his Alert Review QAB to

learn the exact nature of the alert. Pressing the Alert Review QAB causes his console to sequence to the FWC designated target (to place the target in close control) and to display a pairing line between the target and the selected weapon.

(C) If for some reason SWC is unable to engage the target (e.g., if his interceptor does not have sufficient fuel to complete the intercept), SWC responds to the Flag Order by entering the GPFC for Cannot Comply. If he can engage the target, he proceeds to assign weapons to the target.

*Assign Interceptor/Missile*

(C) The procedure used by SWC to assign interceptors and missiles is similar. The SWC Hooks the target, Ball Tabs the interceptor, and presses the Engage Interceptor QAB or Engage Missile QAB, as appropriate. It is not necessary for SWC to Ball Tab own-ship when he elects to engage a target with missiles since the system knows that own-ship's SWC only has control over own-ship's missiles.

(C) This action generates a Target Assigned alert at the IC or FCSC (Fire Control System Coordinator) console. If for some reason the IC or FCSC is unable to engage the target, they press their Cannot Engage QAB which generates a Cannot Engage Alert at the SWC console. At this point SWC may select an alternate weapon, if he has one available, or he may inform FWC that he is unable to engage the target. FWC would in this latter case attempt to assign an alternate force weapon.

*Conduct Intercept*

(C) Based on the geometry of the situation, the relative positions, courses, speeds, altitudes, and ranges of the target and interceptor, the IC operator elects to conduct either a Pursuit or a Collision intercept. If he has

chosen a collision intercept, he presses the Collision QAB, which causes Trial Geometry to be displayed on his PPI; Trial Geometry appears as lines originating from the interceptor and target symbols with the point where they cross indicating the point of intercept, assuming the target continues at its present course and speed. The line drawn from the interceptor also represents a system computed course-to-steer recommendation. If the geometry of the situation is such that the intercept cannot be completed, Poor Situation is displayed on the IC's DRO. The IC may be able to "save" the intercept by increasing the speed of the interceptor (the initial trial geometry is calculated at an arbitrary speed of 0.9 MACH--less than the interceptor's maximum speed). If the intercept cannot be effected, the IC informs the SWC who, in turn, informs the FWC, who selects an alternate weapon to engage the target, if the SWC or IC have not already done so.

(C) Assuming the intercept can be completed and assuming the trial geometry recommendation is acceptable, the IC sends a course and speed order to the interceptor. Once the order has been sent, the IC presses his Order Sent QAB, which causes the interceptor symbol to change to the engaged interceptor symbol.

(C) Orders are sent to the interceptors by voice radio or by automatic data link, Link 4A. When voice radio is used, the IC transmits a control order and then presses Order Sent. When Link 4A is used, the control order is initiated by the pressing of the Order Sent QAB.

(C) When the intercept is completed, the IC informs SWC of its success or failure and presses Cannot Engage to indicate that his interceptor is available for another assignment.

*Select Subsequent Targets*

(C) It is the responsibility of the FWC, SWC, and IC to

insure that weapons are reassigned to subsequent targets as quickly and judiciously as possible after initial engagements are completed. To do this, it is imperative that subsequent targets be selected during engagements and not after they are completed.

*Assign Subsequent Target*

(C) The procedures for assigning subsequent targets are identical to the procedures used for assigning initial targets.

*Engage Subsequent Target*

(C) The procedures used to engage subsequent targets are identical to the procedures used during initial engagement.

*TRK SUP Monitoring Task*

(C) The diagram depicts the four major aspects of the TRK SUP's monitoring task: Monitor TRK Performance, Check Navigational Position, Check Gridlock, and Monitor Data Link Performance. As indicated by the diagram, these tasks are not directly related to target engagement. These tasks are continuous, starting before target-related activity commences and continuing on after target-related activity has been completed.

## OPERATIONAL DATA COLLECTION METHODS

(U) The development of an operational data bank for command-and-control systems must involve consideration of how to collect reliable and valid performance data. Some alternative methods are record keeping of performance errors and times by operational personnel, observations by trained observers, direct recording of overt performance events by hooking equipment into a system, and judgments of performance by experienced operational personnel. Two methods have received most attention in this study: the performance-judgment and direct-recording methods. The feasibility of obtaining reliable judgments of performance errors for a particular operator task was evaluated among experienced system operators. The hardware for direct recording of system events, the Data Recording System (DRS), was developed by NELC; and the software requirements for interpreting the recordings were specified jointly by NELC and HFR.

### *Collection of Performance Judgment Data*

(C) The purpose of collecting performance judgment data was to determine if experienced operational personnel could agree on an ordering of the relative frequency-of-occurrence and importance of errors committed by the TRK SUP. The TRK SUP task was selected for study because his role is central in the NTDS and other operators are aware of his performance--limited access to enough qualified operators did not permit obtaining judgments of the TRK SUP task from TRK SUPs only.

(C) *Procedure*. A preliminary list of some 50 performance errors that the TRK SUP possibly could make was developed from task analysis information. Through interviews with FAAWTC instructors and shipboard personnel, the list was reduced to 35 errors that were judged to be important and to occur with some frequency.

(C) Error statements were developed and a pilot test was conducted with 14 FAAWTC instructors. Their task was to rank the

error statements in order of their relative importance and frequency of occurrence under three instructional sets, different levels of track activity. Their comments were solicited about the format of the statements and the difficulty of the ranking tasks. The subjects indicated that they did not find the tasks difficult, but there was substantial disagreement among them in the ordering of statements.

(C) Based on the pilot test results, the list of error statements was further reduced to 20, and the formats of many were modified. The following 20 error statements were used in subsequent studies.

1. TRK SUP FAILS TO ESTABLISH OWN-SHIP'S TRUE GEOGRAPHIC POSITION TO WITHIN ± 500 YARDS.

2. TRK SUP FAILS TO CLEAR GRIDLOCK PADS PRIOR TO HIS SHIP ASSUMING ROLE OF GRIDLOCK REFERENCE SHIP.

3. TRK SUP FAILS TO DIRECT TRACKER TO CHANGE RANGE SCALES WHEN TACTICAL OR ENVIRONMENTAL CONDITIONS SO DICTATE.

4. TRK SUP FAILS TO DROP OLD TRACKS WITHIN 5 MINUTES AFTER THEY HAVE FADED FROM THE SCOPE.

5. TRK SUP FAILS TO DETECT NEW PIECES OF VIDEO (ASSUMES A SITUATION WHEN THE DET/TRK HAS ALSO FAILED TO DETECT THIS NEW PIECE OF VIDEO).

6. TRK SUP FAILS TO RECOGNIZE AND DROP INVALID TRACKS.

7. TRK SUP FAILS TO RECOGNIZE AND ELIMINATE DUAL TRACK DESIGNATIONS.

8. TRK SUP FAILS TO RESOLVE ALL TRACK CONFLICTS BEFORE ENTERING AN ESTABLISHED DATA LINK.

9. TRK SUP FAILS TO NOTIFY ALFA WHISKEY OF OWN-SHIP'S UNCONTROLLED EXIT FROM DATA LINK WITHIN 1 MINUTE OF EXIT.

10. TRK SUP FAILS TO CHECK THE PERFORMANCE OF THE DATA LINK.

11. TRK SUP FAILS TO OBTAIN A SATISFACTORY GRIDLOCK "FIT" WITHIN 5 MINUTES.

12. TRK SUP FAILS TO USE THE D/A REM THREE-BUTTON ACTION PROCEDURE TO *HAND OVER TRACKING RESPONSIBILITY* FOR TRACKS THAT HAVE FADED FROM HIS SCOPE.

13. TRK SUP FAILS TO RECOGNIZE AND CORRECT EXCESSIVE GRIDLOCK ERROR.

14. TRK SUP SPENDS TOO MUCH TIME TRACKING AND NOT ENOUGH TIME ATTENDING TO HIS SUPERVISORY TASK.

15. TRK SUP FAILS TO CHECK OWN-SHIP'S NAVIGATION POSITION BEFORE MAKING GRIDLOCK CORRECTIONS.

16. TRK SUP FAILS TO RECOGNIZE THAT A LOWER LEVEL OF TRACKER PERFORMANCE IS ACCEPTABLE WHEN TRACKERS ARE OPERATING AT OR NEAR CAPACITY.

17. TRK SUP FAILS TO USE A MUTUAL TRACK WITH A TRACK QUALITY OF 7 (OR THE HIGHEST TQ AVAILABLE) WHEN ESTABLISHING, CHECKING, OR CORRECTING GRIDLOCK.

18. TRK SUP FAILS TO DETECT AND CORRECT OWN-SHIP'S NAVIGATION ERROR WHEN IT EXCEEDS 1000 YARDS.

19. TRK SUP FAILS TO REMAIN COGNIZANT OF THE TRACKING PERFORMANCE OF HIS TRACKERS AND TO TAKE APPROPRIATE CORRECTIVE ACTION WHEN NECESSARY.

20. TRK SUP MAKES A MECHANICAL ERROR SUCH AS INADVERTENTLY ACTIVATING THE BALL TAB, MISREADING A DRO FORMAT, ENTERING THE WRONG FUNCTION CODE (00730 INSTEAD OF 00740), ETC.

(U) Judgment data were collected from subjects on two NTDS ships: 24 on the USS GRIDLEY (DLG 21) and 24 on the USS JOUETT (DLG 29). The subjects represented the following operator functions: SWC, IC, TRK SUP, ID, and DET/TRK (the CO of one ship participated).

(U) The error statements were typed on separate cards, and the subjects were instructed to rank the statements on importance and frequency under two instructional sets, a "routine" situation with few tracks in the system and a "General Quarters" situation with many tracks in the system. Thus,

each subject ranked the 20 statements four times. The ranking conditions were counterbalanced so that the order of conditions was not the same for each subject. The subjects were allowed to take as much time as they needed for each ranking task.

(C) *Results.* Again, the subjects claimed they had little difficulty with the ranking tasks. But there was wide disagreement among subjects on rank positions of the error statements for both importance and frequency of occurrence. The judgments were not reliable in terms of inter-subject agreement.

(C) The mean rank positions for each statement did indicate that discriminations were being made, in spite of subject disagreement. For example, the mean ranks for frequency of occurrence under routine conditions varied from about 6 to about 14 on both ships. Similar variations were observed under the other ranking conditions. But the correlations between ships of the mean ranks for the corresponding ranking conditions were essentially *zero*. The judgments were not reliable, in terms of inter-group agreement.

(C) *Conclusions.* The results of these studies of error statement ranking do not encourage the judgmental data collection method. But there may be some good reasons for the lack of agreement between operators and between ships, other than that the method does not work.

(C) The subjects were not trained observers, even though they were experienced operators. Perhaps most important, they were not "error conscious." In interviews conducted after the judgment sessions, most subjects viewed the NTDS as a "great system" with few faults. And, though they were directly asked, *none* of the subjects identified an additional error to the 20 given them (in spite of the 50 or so errors that were identified earlier). Although errors do occur, their consequences

may not be serious because redundancies in the system permit timely corrections. Such errors may not be perceived as errors at all; or if they are they may not be perceived to be important. If observers are not "alerted" to error occurrence, it is not likely they can make reliable judgments about error characteristics.

(U) Although the particular judgmental method of data collection used "failed" in this instance, there still remains a requirement for judgmental data of operational performance. This is particularly true of the decision-making behaviors occurring between overt responses that cannot be directly recorded or observed. The only source of that data is the decision maker himself. The task remains to devise methods to collect decision-making data in a format suitable for an operational data bank.

*NELC Data Recording System*

(U) The NELC Data Recording System (DRS) has been designed to automatically record, in real time, events that occur in the NTDS.

(C) *Monitoring Capabilities.* A single DRS is capable of monitoring all of the operator actions from fifteen NTDS consoles. All of the fifteen consoles, or any combination thereof, may be individually selected at the DRS front panel controls. All of the Quick Action Buttons (QAB) and function codes from each individually identified operator console can be recorded. Of the 42 available function codes, 26 can be individually included or excluded during data recording, and the remaining 16 are always recorded by the DRS. In addition to recording operator actions, the DRS records the track numbers associated with each action and the system and clock time of each action. The illegal actions taken by each operator are also recorded.

(U) *Shipboard Installation.* The Data Recording System (DRS)

is contained in two semi-portable cabinets. The DRS can be temporarily installed aboard ship in a few minutes. The DRS uses 115 volt, 60 Hz power and interfaces with the NTDS at the Pulse Amplifier/Symbol Generator (Central Pulse Amplifier--CPA). Data acquisition is accomplished without disturbing the integrity of the NTDS: no cable disconnections, no signal loading, and no use of the ship computer.

(U) *Data Recorded.* The following data are recorded by the DRS and stored on magnetic tape:

1. Identification of each console.
2. Mode of each console.
3. Identification of each quick action button.
4. Identification of each function code.
5. Content of each function code.
6. Time of each action (QAB or GPFC).
7. Link 11 track numbers.
8. Own-ship track numbers (CTSL--Central Track Stores Locator).
9. Identification of each console at which each operator's actions take place.
10. Number of illegal actions per console.
11. Identifier information (date, time, ship, observer, etc.).
12. x-y coordinates and range of track.

(U) *Observer Recording.* An on-board observer or observer team is viewed as an integral part of the DRS concept. The observer will note the presence and levels of situational variables, performance characteristics, and the like. The observer data will be used to interpret and order the events recorded by the DRS. Personnel at NELC have suggested the following list of variables that might be observed.

1. Ship class

   a. CVA

   b. DLG

   c. Conversion

2. Sea state/Weather

3. Personal stress factors

   a. Time on station

   b. Time on watch

   c. Watch schedule

      (1) Sleep cycle

      (2) Meal cycle

   d. Operational situation

      (1) Independent exercise

      (2) Multiple unit exercise

      (3) Hostile area

         (a) Routine ops

         (b) Special situation (alert)

      (4) General Quarters

      (5) Regular underway watch

   e. Relations with supervisors

   d. Relations with peers

4. Training factors

   a. Formal school training

   b. On-the-job training

   c. Operational experience

      (1) Conventional CIC

      (2) NTDS

   d. Deployments

5. Personal history

   a. Time in service

b. Time in rate/grade

c. Age

d. Education

6. Team factors

a. Time together as a team

b. Newest member

c. Full team

d. Deployed as team

e. Previous duties in team

7. Equipment factors

a. Sensors

(1) Radar

(a) Equipment not peaked up/inoperative

(b) Inversion layer present

(c) Heavy fog or cloud cover

(2) ECM

(3) SIF/IFF

b. NTDS

(1) Alignment error between radar(s) and consoles

(2) Alignment errors among consoles

(3) Dropped program

(4) Restart program

(5) Console(s) inoperative

(6) Mode(s) inoperative

8. Operators' judgments concerning exercise/operation difficulty and team performance

a. Was the exercise routine with regards:

(1) Number of friendly tracks

(2) Number of hostile tracks

(3) Normal NTDS AAW procedures

(4) Radar performance

(5) NTDS equipment performance

b. How well the team performed:

(1) Very well

(2) Better than average

(3) Average

(4) Below average

(5) Not well

c. Was the team unusually

(1) Bored

(2) Tired

(U) *Data Reduction.* The data is recorded on tape in a format to match the input requirements of the particular computer that will be used for the analysis. The first unit is compatible with an IBM 360 computer. The first output is an English language listing of the data as recorded, decoded to the applicable NTDS software. An analyst then adds to the raw data all of the observer data accompanying the recording from the ship. The augmented list is then re-run through the computer to produce a permanent Input Data List which will become part of an ever-increasing data file. All sorting, statistical summaries and exercise reconstructions will be produced from the Input Data Lists.

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# DEVELOPMENT OF A TAXONOMY OF HUMAN PERFORMANCE

(U) One of the more important characteristics of an operational data bank is the level of description of task performance. And the level of description is largely determined by the scheme used to classify task performance. Task performance may be classified at a relatively *molecular* level, such as in terms of the psychomotor responses required in a sequence of button-pushing actions; or at a relatively *molar* level, such as in terms of the task functions served by a sequence of responses. Which classification scheme is "better" depends entirely on how it is to be used. If one scheme "works," provides useful information, in a given application, then it is "better" than a scheme that does not.

(U) The notion that one can develop a taxonomy, similar to those found in the biological and physical sciences, of human performance is probably illusory--if by 'taxonomy' we mean 'classification in terms of essential characteristics.' What is "essential" in one situation may not be in another. The best one can hope for is to develop a *useful* taxonomy.

(U) There are four major requirements for a useful taxonomy of human performance:

1. That the terms be exhaustive; that no other terms are needed to describe task performance.

2. That the level of description implied by the terms be appropriate in the situations where the taxonomy is applied.

3. That the user of the taxonomy be taken into account; that the taxonomy be an effective communication device.

4. That the common or special connotations of the terms of the taxonomy be taken into account; one should both take advantage of well-established meanings of terms and be careful not to interfere with communication by redefining terms.

(U) Several taxonomies were reviewed in the course of this study. The one that seemed best to apply to command-and-control systems is the taxonomy developed by Miller (1971). One of his purposes in developing the taxonomy corresponded to one of our purposes: to communicate with engineers. His terms were selected with that purpose in mind. Miller's taxonomy, which he called a "systems task vocabulary," and his simplified description of each term is given below.

| TERM | SIMPLIFIED DESCRIPTION |
|---|---|
| MESSAGE | A collection of symbols sent as a meaningful statement. |
| INPUT SELECT | Selecting what to pay attention to next. |
| FILTER | Straining out what does not matter. |
| QUEUE TO CHANNEL | Lining up to get through the gate. |
| DETECT | Is something there? |
| SEARCH | Looking for something. |
| IDENTIFY | What is it and what is its name? |
| CODE | Translating the same thing from one form to another. |
| INTERPRET | What does it mean? |
| CATEGORIZE | Defining and naming a group of things. |
| TRANSMIT | Moving something from one place to another. |
| STORE | Keeping something intact for future use. |
| SHORT TERM STORAGE (BUFFER) | Holding something temporarily. |
| COUNT | Keeping track of how many. |
| COMPUTE | Figuring out a logical/mathematical answer to defined problem. |
| DECIDE/SELECT | Choosing a response to fit the situation. |
| PLAN | Matching resources in time to expectations. |
| TEST | Is it what it should be? |
| CONTROL | Changing an action according to plan. |
| EDIT | Arranging/correcting things according to rules. |
| DISPLAY | Showing something that makes sense. |

| TERM | SIMPLIFIED DESCRIPTION |
|---|---|
| ADAPT/LEARN | Remembering new responses to a repeated situation. |
| PURGE | Getting rid of the dead stuff. |
| RESET | Getting ready for some different action. |

(U) In developing our taxonomy, we have leaned heavily on Miller's. Some of his terms have been omitted, some have been combined, and some new ones have been added. The taxonomy that is presented below is viewed as a preliminary one whose usefulness remains to be determined. It has been evaluated by HFR staff engineers, but a more formal evaluation and test of its application is required.

*A Taxonomy of Human Performance*

1. *Message*

(U) *Definition.* 'Message' stands for 'a pattern of symbols or signals that activates (or could activate) a process that results in a useful system response.'

(U) *Comment.* Miller said, "the concept of message may, like stimulus in psychology, be a fundamental one" (p. 23). He suggested that the term 'message' may not be formally defined in a descriptive system, such as this one, but rather would gain its meaning, by example, from the context in which it is used. Indeed, the definition given above conveys little about what a message is, without exemplification. Messages in the man-machine systems we are interested in may occur in any one of these formats:

a. A language symbol pattern. The meaning of a message in language symbols is determined by rules of grammar, semantics, and reference. For example, "You are too far to the right of the target" has meaning in a given context to those who understand English. The message may be abbreviated ("right" for the above message), but its meaning still depends on language rules. The abbreviation, of course, stands for the entire message. Language-symbol

messages may be communications from man to man, such as voice commands, or from machine to man, such as a computer printout in English.

b. A non-language symbol pattern. The meaning of a message in non-language symbols is determined by special reference rules. For example, '→' in one context may stand for 'turn right'; in another context, 'you are too far to the right.' A red light or a high-pitched tone may stand for 'danger,' 'stop,' or any statement it is referenced to. Non-language symbols have no necessary correspondence to their referents, but the form of the symbols may simplify interpretation: a symbol that stands for 'aircraft' may be a circle or a line drawing of an aircraft. The drawing conveys the message "aircraft" directly; the circle requires an intermediate process, 'circle' stands for 'aircraft.' Non-language-symbol display messages may be communications from man to man or from machine to man.

c. A signal pattern. The meaning of a signal pattern also is determined by special reference rules, but a given pattern may have a close correspondence to characteristics of its referent. For example, a signal pattern displayed on a sonar PPI scope may signify, in addition to the presence and location of a target, the nature of the target--that it is a submarine of a given size and aspect. The characteristics of signal patterns may bear a one-to-one relationship to certain characteristics of referents. The relationships between signal-pattern and referent characteristics are not always known, but the potential exists to establish the relationship where the displayed signal pattern is a transformed form of the energy pattern sensed from the referent. The essential difference between a non-language symbol pattern and a signal pattern lies in their referent relationships. In the first, the relationship is arbitrarily defined: 'X' stands for 'Y'; in the second, the relationship also is defined but may be functionally specified: X = f(Y). Signal-pattern messages are communications from machine to man.

d. A control pattern. The meaning of a control-pattern message is determined by rules of correspondence between control activation and consequence. For example, pushing a button labeled "SEQ" results in removal of a present message and presentation of a

new message on a display. Movements of a control lever may result in corresponding movements of a symbol on a display or movements of a vehicle. A control-pattern message may be a single button push, repetitive pushes of a single button, a sequence or pattern of button pushes, or discrete or continuous movement of a variable control. Control-pattern messages are communications from man to machine; the machine may change its functioning or that of another machine in response to the message, or it may process the message and display it or some other message to a man.

(C) Messages may be in other formats: hand signals, facial expressions, direct sense impressions of the environment, all may be messages in the sense that they activate some response. But the four message formats described above--language symbol, non-language symbol, signal, and control patterns--are the relevant ones for command-and-control, man-machine systems. These are the formats the system engineers must consider in the design of an information-processing system, and in the allocation of functions to men or to machines. A case could be made that the basic analysis of a man-machine system is done in terms of the message requirements of the system. What are the necessary messages? What messages should be processed by men, by machines? What are the message format and display requirements for machine-to-man communications? What are the control message requirements for man-to-machine communications? Questions like these are posed and answered implicitly or explicitly in the design evolution of any man-machine system. For example, in the NTDS system, the designers doubtlessly considered the question, "How should the target be displayed to the DET/TRK?" Their decision was to display the radar raw video on the PPI; that is, the detection task was assigned to man, and the message format was a signal pattern. Their reasons for the decision were probably based on the fact that man is a better detector than machine in this situation. But the DET/TRK also makes other than a detection response to the video or signal-pattern message. He locates the initial position

of the target represented by the signal pattern and keeps track of its position on successive presentations of the pattern. He does this by aligning a small circular symbol with the "center leading edge of the video" and then pushing an appropriate button to enter the position. It could be that once a target is detected and entered into the system the signal-pattern message format has served its purpose; for the subsequent location responses, perhaps the machine could solve for the "center" and present a non-language symbol representing it that would make the operator's alignment task easier and more accurate. The point of this discourse is not that the message format is necessarily inappropriate for the tracking task--we don't know if it is or not--but that the selection of format obviously depends on the kind of information conveyed by the message and the nature of the response to it.

(U) The content of a message may be data ("this is a hostile target") or instruction ("destroy the target") or both ("this is a hostile target; destroy it"). Actually, all relevant system messages imply "instructions"; that is, they must result in response decisions or actions. Indeed, an operational definition of the "meaning" of a message would be in terms of the response to it. A data message such as "hostile target" not only indicates the presence of a target but generates a series of decisions and actions: "it is a threat to us or it is not," "determine the characteristics of the target," "keep track of it," "destroy it," and so on. It is evident that the "total" meaning of a message depends on the context in which it occurs.

(U) The definition of "message" includes the phrase "results in a useful system response." The intent here is to distinguish between messages and non-messages in a given system. Non-messages may be perceived as messages, such as interpreting a signal pattern as a target of interest when in fact it

is not. If a non-message is responded to as if it were a message, the result may be responses that are not only not "useful" to the system but that degrade system performance. If system non-messages are perceived as such, the responses to them would be useful system responses. Perhaps the non-message concept is not really necessary (a signal-pattern message could signify "noise") but it seems convenient in analyzing the significance of events in a *given* system. Again, the context would determine whether an event was a message or non-message.

(U) There are literally thousands of messages in a complex system like the NTDS. Some examples by message format follow.

(C) *Language symbol messages*. Radio voice communications are an integral part of the system. The TRK SUP may tell the DET/TRK "check the area indicated by the pointer for a target," "update your trouble tracks," or "your tracking performance is lousy." The IC may tell an interceptor pilot the course, speed, and altitude he is to fly to intercept a hostile aircraft. The FWC may ask for a CID report from the TRK SUP; the TRK SUP responds by voice. Language symbol messages also are displayed on operator consoles such as on DRO and Alert panels, and may signify characteristics of a target or instructions of what to attend to next. Control identifications are generally in language-symbol format.

(C) *Non-language symbol messages*. There are many non-language symbol messages: symbols that identify tracks ('/\' for 'air hostile'), that indicate some action taken ('△' for 'air hostile engaged by interceptor'), that indicate some action to be taken (a flashing symbol for 'trouble track'), that locate a track ('⊙', the Ball Tab symbol), or that designate an area of interest ('⊡', the Pointer symbol). Other non-language symbols include light and sound identification or warning messages.

(C) *Signal-pattern messages.* The message that initiates the purposive behavior of the system is a signal-pattern message, the radar raw video displayed on the PPI. Other signal-pattern messages are presented on ECM and IFF displays, primarily for clarification and amplification of the basic message. But the significant signal-pattern message in the NTDS is the video corresponding to the targets sensed by radar.

(C) *Control-pattern messages.* There are also a great many control-pattern messages: control actions that indicate a target has been detected and located (Ball Tab and Enter New Track actions), that keep track of targets (Ball Tab and Position Correction actions), that request additional information (Function Code actions), that instruct another operator (Engage Target action), that inform another operator (Engaged Target action), that test decisions (Intercept-Trial geometry action), and that affect message clarity (PPI display adjustment actions). Most NTDS messages are initiated by activation of console controls.

2. *Display/Receive*

(U) *Definition.* 'Display/receive' stands for 'presenting messages in a format for human reception.'

(U) *Comment.* This term and all subsequent ones are defined as processes. Messages, of course, are the basic units that are processed. We have added 'receive' to Miller's term to emphasize that both a process and a human receiver are referenced. An analysis of performance in a given situation must take into account the characteristics of the displaying equipment and message format.

3. *Control/Transmit*

(U) *Definition.* 'Control/transmit' stands for 'initiating the transfer of a message from one place to another.'

(C) *Comment.* We have combined two of Miller's terms to arrive

at this term, perhaps unwisely. It seems to us, though, that it is convenient to think of control actions as initiators of the transmission of a message. For example, rolling the Track Ball sends a message to the computer that is processed and results in changes in the position of the Ball Tab. Our engineers tend to feel that the terms should be separate, that 'control' should mean something like 'directing a physical action.' But if messages are the things processed, then...well, we shall reserve judgment.

4. *Input Select*

(U) *Definition.* 'Input select' stands for 'determining the priority of a message or message channel.

(C) *Comment.* We have included Miller's "queue to channel" concept in the definition of this term. The input select process may be initiated by a message from the external environment, such as a flashing symbol indicating "trouble track"; or by an operator simply deciding what to attend to next, such as the TRK SUP evaluating the performance of a DET/TRK.

5. *Filter/Purge*

(U) *Definition.* 'Filter/purge' stands for 'eliminating irrelevant information, non-messages, or unwanted messages.

(U) *Comment.* Two of Miller's terms are combined. They seem to us to mean about the same thing, even though 'filter' has a special meaning for engineers. This combination may violate a principle earlier stated about established meaning of terms.

6. *Search/Detect*

(U) *Definition.* 'Search/detect' stands for 'scanning a field and determining if a message is present.'

(U) *Comment.* This combining of terms makes a great deal of sense to us. Search usually involves a "search image" (Miller

pointed this out); that is, somebody is looking for something. When a message is perceived that "fits" the image, a detection occurs.

7. *Classify/Identify*

(U) *Definition.* 'Classify/identify' stands for 'assigning a message to categories and naming the message or the categories.'

(U) *Comment.* We have substituted 'classify' for Miller's 'categorize' and combined it with his 'identify.' The terms already have rich connotations, and we feel that different levels of the same process are involved in classification and identification.

8. *Interpret*

(U) *Definition.* 'Interpret' stands for 'determining the meaning of a message and its significance to system objectives.'

(U) *Comment.* A message may be classified and identified and otherwise processed, but its significance must be assessed before effective action can be taken.

9. *Code/Edit*

(U) *Definition.* 'Code/edit' stands for 'changing a message from one format to another and selecting a suitable format.'

(U) *Comment.* Perhaps the two concepts of Miller should not be combined, but changing a message format seems to us to always involve an editing process. The process refers to both encoding and decoding actions.

10. *Long-Term Store*

(U) *Definition.* 'Long-term store' stands for 'holding something in memory from one system evolution to another.'

(U) *Comment.* 'Evolution' refers to the series of actions that take place within a given time span of system performance.

Examples of long-term store are the operator procedures and the computer processing programs that are common from one evolution to another. For contrast, see the next term.

11. *Short-Term Store*

(U) *Definition.* 'Short-term store' stands for 'holding something in memory within the time-span of a system evolution.'

(U) *Comment.* Examples of short-term store are the identifications of targets, the status of friendly aircraft, or the location of hostile aircraft; in short, most messages that are processed in one system evolution are held in short-term memory for varying periods of time but are not carried over to the next evolution (what is *learned* from the processing activity may be "transferred" to long-term memory).

12. *Plan*

(U) *Definition.* 'Plan' stands for 'anticipating conditions, considering options available, and assigning probable responses.'

(U) *Comment.* Effective use of the planning process can have a significant effect on the quality of subsequent performance and on response times to new messages, particularly in decision-making activities.

13. *Interrogate*

(U) *Definition.* 'Interrogate' stands for 'seeking information that is not presently displayed.'

(U) *Comment.* Miller did not use this term and did not seem to have a correlative one in his taxonomy. It seems important to distinguish this process, particularly in computerized systems where much information is held in long- or short-term store. Of course, humans are interrogated, as well.

14. *Analyze/Compute*

(U) *Definition.* 'Analyze/compute' stands for 'determining the relationships among messages or elements of a message.'

(U) *Comment.* We have added 'analyze' to Miller's 'compute' to take advantage of the connotations of the term and to broaden the concept a bit. 'Compute' generally refers to a mathematical process; the expanded term includes other logical, non-mathematical, processes.

15. *Test/Compare*

(U) *Definition.* 'Test/compare' stands for 'determining whether a message or a response is valid or appropriate.'

(C) *Comment.* We have added 'compare' to Miller's term to include an important element of the testing process. We think of the test/compare process as applying to testing a specific hypothesis. For example, the process is involved when the DET/TRK compares the position of the Ball Tab to the estimated position of the "center leading edge" of the video and decides whether the positions correspond. The process is also involved when the IC calls for (interrogates) trial geometry to determine if an intercept-target assignment will likely result in an interception.

16. *Estimate*

(U) *Definition.* 'Estimate' stands for 'assigning a value to an event or to the occurrence of an event.'

(C) *Comment.* Miller did not include this term, but it seems important in an information-processing system. For example, the IC estimates the change in the time and location of an interception that would result if he ordered a change in speed of the interceptor. He also may estimate the weapon release point (time) of a hostile aircraft to determine if a timely interception will occur.

17. *Evaluate*

(U) *Definition.* 'Evaluate' stands for 'determining the status of a situation and its value to system objectives.'

(C) *Comment.* Miller did not have this term, but it may be implied by other terms in his taxonomy. Evaluation may include testing and comparing, but the level of hypotheses testing is much "higher" and applies to broader objectives, rather than to narrow specific objectives as does the test/compare process. For example, the FWC evaluates the tactical situation in considering how to deploy forces. He may also evaluate the threat to his forces of hostile forces. The evaluate process is an integral part of the decision-making activities in command-and-control systems.

18. *Decide/Select*

(U) *Definition.* 'Decide/select' stands for 'considering alternatives and determining an appropriate course of action.'

(C) *Comment.* The decide/select process is perhaps the most significant process in command-and-control system task performance. It is present at all levels of system performance: from the DET/TRK, who decides what track to attend to next, to the FWC, who decides upon the deployment of his forces. And it is also the process that is most difficult to study to determine what is going on between overt response events.

*Error Classification*

(U) The error classification scheme that is appropriate is largely implied by the taxonomy. Thus, we may identify an interpret error, a control/transmit error, a display/receive error, and so on. This has the advantage of relating the error to the process ongoing at the time it occurs. But it is also necessary to identify the *type* of error that occurs to better understand the reasons for the occurrence of the error. Therefore, we propose a two-level error classification

scheme; one level based on taxonomy terms, and the other on the type of error, as described below.

(U) *Omission error.* Failure to make a required response, or to receive a message.

(U) *Commission error.* Making an inaccurate response to a received message.

(U) *Substitution error.* Making the wrong response to a message.

(U) *Sequence error.* Making a response out of order.

(U) *Time error.* Failure to make a response in a given time period, or at a timely point.

# CHARACTERISTICS OF AN OPERATIONAL DATA BANK

(U) The main purpose of this study was to determine the characteristics of an operational data bank for command-and-control systems. We have identified some minimal characteristics required if the operational data bank is to be useful. These characteristics are described, by example, on the following pages. Some assumptions have been made in selecting the content and format of the data bank.

(U) First, we have assumed that the primary user of the data bank will be the system designer, though not necessarily the exclusive user. The format of the data bank, then, must be in terms the engineer understands and the data in a form he can use. The data bank should also be available and provide useful information to other users. The manager of an existing system should be able to refer to the bank for *performance standards*, obtained under different operating conditions, to evaluate his operation of the system. The person charged with *manning* a system should be able to refer to the bank to select operators on variables related to effective performance. The person charged with *training* should be able to refer to the bank to determine training requirements and performance criteria.

(U) Second, we have assumed a level of description of task performance. It is a relatively molar level, largely determined by the terms of the preliminary taxonomy of human performance described earlier. However, if information is available about intermediate levels of performance, it should be included in the bank. In the example task, described below, we have identified the *response sequence* as well as the major *task events*.

(U) Third, and very important, we have assumed the existence of a data bank *compiler*, someone who *interprets* the significance of operational data and *translates* it into terms the

user can understand. Although this is an *operational* data bank, the compiler would refer to other sources, including laboratory research literature, in making his interpretations. The engineer, generally, must make his design decisions *now*; the bank should provide him with all relevant data, even though extensive operational data may not be presently available.

(U) We have shown in Table 2, on the pages following this discussion, an example of what a data bank readout might look like. We have assumed what we call a Detect and Locate task, and we use an actual task from the NTDS for illustration. However, all of the data are hypothetical. The main sections of the data bank readout are discussed below.

(U) *System and Equipment.* The machine involved in the performance of a man-machine task must, of course, be thoroughly described. Whether the machine description be incorporated in the data bank or whether the data bank references another source for the description probably depends on the extensiveness of the machine documentation and its availability to the data bank user. In the case of the NTDS example task, we have *identified* the relevant equipment and *referenced* the source documents.

(U) *Task Description.* The sequence of *performance* events in the task must be described in detail, and the significant *task* events must be identified and associated with the respective performance events. We believe that the performance data in the bank should apply to task events, that those data will prove most useful to the design engineer. In the example, the task events are *detect*, *locate*, and *task complete*. The *response sequence* associated with the task events is identified also. The messages processed during the performance of the task are identified. The format of the messages will be best appreciated by careful study of the display and control features of the relevant equipment.

(U) *Performance Measures.* The relevant dependent variables must be identified and operationally defined. What variables are relevant will depend on the particular task and on the task events identified. In the example, the dependent variables are detection time, location time, task completion time, false alarm frequency, and location accuracy. The performance measures derived from these variables are probability of correct response by time (for *detect*, *locate*, and *task complete* events), false alarm rate, and the mean and standard deviation (or other appropriate summary statistics) of location error.

(U) We believe that the most significant dependent measure to observe in command-and-control systems tasks is the probability of correct response by time. Figure 3 shows a hypothetical function for the *detect* event of the example Detect and Locate task.

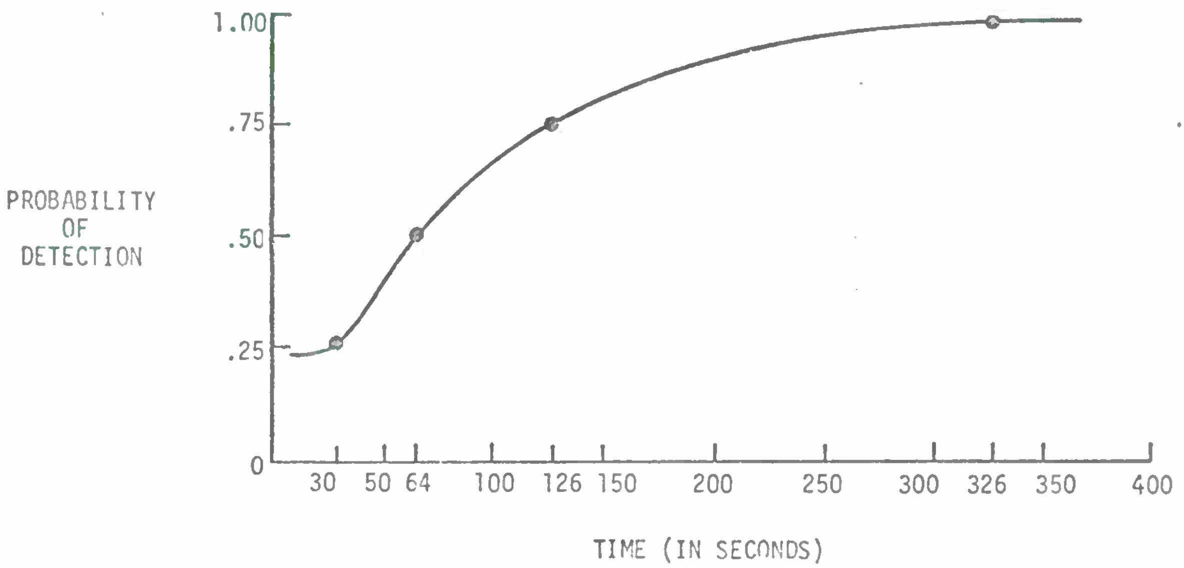


Figure 3. Probability of detection (correct response) x time (in seconds).

(U) The probability of correct response is defined as the ratio of correct detections to the total number of *opportunities* to detect. The function may represent the detection performance of an individual or that of a group of individuals. The design engineer is most interested in group performance,

given the characteristics of the group and the conditions of performance (see below). In the illustration, the opportunity to detect occurred when a signal-pattern message was first displayed (at zero time): 25% of the task performers detected the message by 30 seconds; 50% by 64 seconds; and 99% by 326 seconds.

(U) The major criterion of command-and-control system effectiveness is the response time required for effective action. If the design engineer has available such probability-by-time functions, based on operational data, for the several command-and-control tasks and task events, he may be able both to evaluate and to simulate alternative system configurations.

*Performance Data*

(U) The format the data is presented in depends on the performance measure. Whenever time to respond is a significant variable, the format is probability of correct response as a function of time. In the example, the major data follow that format; but they are presented in tabular rather than graphic form, as shown below for the *detect* task event data (the table entries are times in seconds).

| Task Event | Probability of Correct Response | | | |
|---|---|---|---|---|
| | .25 | .50 | .75 | .99 |
| Detect | 30 | 64 | 126 | 326 |

(U) The performance data are presented at several levels: overall compilations for each dependent measure and breakdowns by significant independent variables when the variables are identified and reliable data is available (in each case, the number of observations on which the data are based is indicated). The significant independent variables will be "performance shaping factors"; that is, variables that make a

difference in performance. In the example, we have included a few such variables likely to have an important effect on performance of a detect and locate task: operator experience, operator time on station (at the task), number of system tracks (competing messages, task load), and range of target (some significant variables will vary by task). Hypothetical data are presented for selected task events by the significant variables.

(U) In the example, false alarms are given as a ratio, number of false alarms to total number of targets detected and located. Location errors are transformed into discrepancies in miles between true and computed target position.

*Summary*

(U) This is the province of the compiler. The general conditions of the operational data collection are identified (e.g., fleet exercises over several days), the data are interpreted, and other relevant data sources are referenced. The example summary makes sense, in terms of the hypothetical performance data and what is known about this kind of task.

TABLE 2

HYPOTHETICAL EXAMPLE OF DATA BANK READOUT
DETECT AND LOCATE TASK

A. System and Equipment

1. Naval Tactical Data System

   a. UYA-4 Console

   b. AN/SPS-48 Radar

2. Reference: Program Operation for Model III, Phase I, PD-6072 (Vol. II and III)

B. Task Description

1. Initiating message: signal pattern, raw radar video

2. Response messages: control pattern actions

3. Task sequence:

| Task Event | Response Sequence |
|---|---|
| a. Detect . . . . . . . | (1) Enable Ball Tab |
| | (2) Position Ball Tab |
| | (3) Push Hook QAB |
| b. Locate . . . . . . . | (4) Enter New Track |
| | (5) Position Correction QAB* |
| | (6) Position Correction QAB |
| c. Task Complete. . . | (7) Position Correction QAB |

4. Confirmation messages: non-language symbol patterns

   a. Tentative Track symbol; after (4) Enter New Track; remains through (6)

   b. Firm Track symbol; after (7)

*Note: If Position Correction QAB not activated in 72 seconds after Enter New Track, the system automatically drops this track. Similarly, if the elapsed time between Responses 5, 6, and 7 exceeds 72 seconds, the track will be dropped automatically.

C. Performance Measures

1. Detection time: time between signal pattern entry and Enable Ball Tab

TABLE 2
(Continued)

2. Location time: time between signal pattern entry and Enter New Track

3. Task completion time: time between signal pattern entry and third position correction QAB

4. False alarm frequency: number of times track dropped

5. Location accuracy: estimated discrepancy between Ball Tab position and center leading edge of signal pattern transformed to miles between true and computed target position

D. Performance Data

1. Probability of correct response by time in seconds (N = 100)

a. Overall

| | Probability of Correct Response | | | |
|---|---|---|---|---|
| Task Event | .25 | .50 | .75 | .99 |
| Detect | 30 | 64 | 126 | 326 |
| Locate | 36 | 71 | 131 | 332 |
| Task Complete | 191 | 221 | 309 | 485 |

b. By Operator Experience (for *Detect* task event only)

| | Probability of Correct Response | | | | |
|---|---|---|---|---|---|
| Experience Level | .25 | .50 | .75 | .99 | N |
| < 3 mos. | 52 | 140 | 245 | 492 | 21 |
| 3-6 mos. | 38 | 61 | 115 | 319 | 28 |
| > 6 mos. | 25 | 51 | 106 | 228 | 51 |

TABLE 2
(Continued)

D. Performance Data (continued)

c. By Operator Time on Station (for *Locate* task event: Time to Position Ball Tab only)

| Time on Station | Probability of Correct Response .25 | .50 | .75 | .99 | N |
|---|---|---|---|---|---|
| 0-30 min. | 3 | 4 | 4.5 | 5 | 23 |
| 31-60 min. | 3.5 | 5 | 6 | 8 | 24 |
| 60-240 min. | 5 | 7 | 8 | 8.5 | 42 |
| 240+ min. | 8 | 10 | 10.5 | 12 | 11 |

d. By Number of System Tracks (for *Task Complete* event only)

| Number of Tracks | Probability of Correct Response .25 | .50 | .75 | .99 | N |
|---|---|---|---|---|---|
| 1-3 | 163 | 208 | 274 | 342 | 28 |
| 4-6 | 158 | 204 | 286 | 405 | 35 |
| 7-10 | 208 | 216 | 333 | 582 | 24 |
| 11 or more | 234 | 265 | 384 | 609 | 13 |

TABLE 2
(Continued)

D. Performance Data (continued)

e. By Range of Target (for *Locate* task event only)

| Range | Probability of Correct Response .25 | .50 | .75 | .99 | N |
|---|---|---|---|---|---|
| 0-60 miles | 20 | 31 | 39 | 52 | 23 |
| 60-140 miles | 23 | 58 | 142 | 201 | 23 |
| 140-210 miles | 38 | 93 | 178 | 305 | 41 |
| more than 210 | 47 | 138 | 233 | 408 | 13 |

2. False Alarm Rate

a. Overall

5/100 = .05 rate

Note: Data base not adequate for additional breaks

3. Location Accuracy Error in Transformed Miles

a. Overall

Mean Error = 3.0 miles
SD = 1.25 miles
N = 100

b. By Range of Target

| Range | Mean Error | SD | N |
|---|---|---|---|
| 0-60 miles | 3.1 | 1.10 | 23 |
| 60-140 miles | 1.8 | 0.61 | 23 |
| 140-210 miles | 2.8 | 0.92 | 41 |
| > 210 miles | 5.8 | 2.15 | 13 |



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TABLE 2
(Continued)

c. By Number of System Tracks

| No. of Tracks | Mean Error | SD | N |
|---|---|---|---|
| 1-3 | 2.7 | 0.88 | 28 |
| 4-6 | 2.1 | 0.71 | 35 |
| 7-10 | 3.6 | 1.13 | 24 |
| > 11 | 5.1 | 2.18 | 13 |

## E. Summary

Compare Detect and Locate performance for operators using the AN/SPS-48 and the AN/SPS-40 Radar. Use search terms Detect and Locate tasks, NTDS, UYA-4, and AN/SPS-40 Radar. The AN-SPS-48 produces both a reduced rate of false alarms and greater location accuracy. The data indicate that the optimum elapsed time between updates is 50-65 seconds; when either more or less than 50-65 seconds elapse between updates, tracking tends to be less accurate; when 1-6 system tracks are present, updates tend to occur during the optimum time; when the number of tracks increases, updating behavior becomes random and frequently occurs both sooner and later than the optimum time.

Note that for the break by number of system tracks, D.1.d., performance is better when 4-6 system tracks are present than when only 1-3 tracks are present. In addition, a very significant time differential can be noted between the .50 and .75 levels of probability of correct response when 7-10 system tracks are present.

Note that initial location accuracy for close in, 0-60 miles, is not as good as for targets between 60 and 210 miles. The apparent cause of this differential is a lack of deliberation by the operator in entering Late Detect targets.

# RECOMMENDATIONS FOR FURTHER RESEARCH

(U) We have taken some steps towards developing a taxonomy of human performance, the characteristics of an operational data bank, and methods of collecting operational data. But we have barely scratched the surface of what needs to be done. We recommend that continued research be focused on these areas--performance taxonomy, operational data bank, data collection methods--and that the NTDS continue to be the command-and-control system under study.

*Taxonomy of Human Performance*

(U) Further research on the taxonomy should be directed toward whether or not it meets two major purposes: communication with systems engineers and a useful level of task description. To determine if the taxonomy meets the first purpose, engineers and system designers have to be exposed to the taxonomy. We recommend that substantial numbers of engineer/designers be interviewed to assess the strengths and weaknesses of the taxonomy. The result should be an effective communication device. To determine if the taxonomy meets the second purpose, more accurate descriptions of command-and-control tasks are needed. We believe that our descriptions of the NTDS tasks are probably reasonably accurate, but they lack an essential input: substantial operational data. We recommend that operational performance data be collected on the NTDS (see below).

*Characteristics of an Operational Data Bank*

(U) Further research on data bank characteristics should be directed toward whether or not the systems engineer/designer finds the bank useful. We recommend, as for the taxonomy, that substantial numbers of engineer/designers be interviewed to determine just what characteristics are required to make the data bank a useful tool. It would be pointless to assemble

a data bank at considerable cost if it were not used by the intended users.

*Data Collection Methods*

(U) The most important requirement for further research is to continue the development of data collection methods and to collect operational data. On the next several pages is a detailed plan for collecting operational data from the NTDS. The plan is organized by NTDS tasks. The following specifications are included:

1. The data required to evaluate task performance.

2. The data sources (the data collection methods) and what data may be obtained from them; the methods are direct recording (the DRS), observer recording, and interview. "Interview" includes the judgmental data collection methods.

3. The reduced data required for the data bank and for task evaluation.

(U) We recommend that the data be collected aboard ship during operational exercises, so that validation data may also be collected.

DATA COLLECTION PLAN

*Task 1: Search*

(C) *Data Required:* The search activity and strategy of the NTDS team.

1. Identity of consoles engaged in search.
2. Mode, radar, range scale, and search sector by console.
3. Search strategy rationale.

(C) *Data Sources:* The data required is available.

1. Data Recording System.
   a. Mode and radar by console (A-12 Panel QAB).
   b. Size, shape, location of search sector (Ball Tab x-y position when Entry Offset QAB entered at A-11 panel).
2. Observer Recording.
   a. Range scale by console.
   b. Operator search behavior.
3. Interview.
   a. Rationale for search assignments (TRK SUP).
   b. Rationale for search procedures (TRK SUP).
   c. Judgments of difficulty of search task (TRK SUP and DET/TRK).

(C) *Reduced Data Required*

1. Tabulation of search mode, radar, range scale, and sector by console.
2. Scaling of search difficulty measures.

*Task 2: Detect*

(C) *Data Required:* The conditions of detection.

1. Target type (signal-pattern referent).
2. Characteristics of signal pattern: size, S/N ratio.
3. Time of signal pattern display entry.
4. Time of detection.
5. Range of detection.
6. Identity of detecting console.

(C) *Data Sources:* The appearance, location, or characteristics of raw video are not directly fed into the computer system; the computer is informed of the presence of a signal pattern only when the detection response is made.

1. Data Recording System.
    a. Time of detection (New Track or Late Detect QAB).
    b. Range of detection (Ball Tab x-y position and New Track QAB).
    c. Console detecting.
2. Observer Recording.
    a. Target type and signal pattern characteristics.
    b. Possibly time of signal pattern entry.
    c. Operator behavior and attentiveness.
    d. Predicted detection range (from Fade Charts).
    e. False detections.
3. Interview.
    a. Detection criteria used (TRK SUP and DET/TRK).

b. Detection decision behavior (TRK SUP and DET/TRK).

c. Judgments of difficulty of detection task (TRK SUP and DET/TRK).

(C) *Reduced Data Required*

1. Detection time (difference between signal pattern entry and detection).

2. Detection range (distance between own-ship or Vital Center and target).

3. Frequency of false detections.

4. Scaling of decision behavior measures by detection criteria.

5. Scaling of detection task difficulty measures.

*Task 3: Track Entry and Monitoring*

(C) *Data Required:* The conditions of track entry into the system and subsequent track corrections.

1. Time of Tentative Track entry (detection).
2. Time of Tentative Track update.
3. Time of Firm Track entry.
4. Time of Firm Track update.
5. Time of Late Detect entry.
6. Operator time to enter or update track.
7. Total time track is in system.
8. Distance traveled by target by track update events.
9. Tracks dropped automatically by system.
10. Tracks dropped by operators.
11. Accuracy of track location.
12. Occurrence of track confusions.
13. Time of track confusion and time of resolution.
14. Identity of console.

(C) *Data Sources:* Track accuracy cannot be recorded directly, because the position of raw video is not available to the computer.

1. Data Recording System.
   a. Time of Tentative Track entry (New Track QAB).
   b. Time of Tentative Track update (Position Correction QAB before Firm Track status).
   c. Time of Firm Track entry (Position Correction QAB).
   d. Time of Firm Track update (Position Correction QAB).

e. Time of Late Detect entry (Late Detect QAB).

f. Operator time to enter or update track (Enable Ball Tab button and New Track or Late Track or Position Correction QAB).

g. Total time track is in system (New Track or Late Detect QAB and Drop Track QAB or automatic drop of track number).

h. Distance traveled by target (Ball Tab x-y position and QAB actions).

i. Times of track confusions and resolutions (Nav check, Gridlock Check, and Drop Track QAB).

j. Console responding.

2. Observer Recording.

a. Tracking accuracy: direct observation of DET/TRK performance.

b. Tracking accuracy: inferred from track history display.

c. Operator entry and tracking behavior.

3. Interview

a. Judgments of tracking accuracy (TRK SUP and DET/TRK).

b. Judgments of overall tracking performance (TRK SUP, IC, and SWC).

c. Judgments of tracking difficulty (TRK SUP and DET/TRK).

d. Identification of track confusion problems (TRK SUP).

e. Reasons for dropped tracks (TRK SUP and DET/TRK).

(C) *Reduced Data Required*

1. Operator entry and update times.

2. Time between Tentative Track updates.

3. Time between Firm Track updates.

4. Total time track is in system.

5. Number and rate of tracks per unit time.

6. Number of tracks dropped by reason.

   a. Tentative Tracks.

   b. Firm Tracks.

7. Number of tracks dropped and reentered.

8. Number of track confusions.

9. Time to resolve track confusions.

10. Scaling of tracking accuracy measures.

11. Scaling of overall tracking performance measures.

12. Scaling of tracking difficulty measures.

*Task 4: Track Identification*

(C) *Data Required:* The identification performance of the ID and other operators.

1. Target type and characteristics.
2. Time of Tentative Track entry (detection).
3. Time of Firm Track entry.
4. Time of ID Close Control action.
5. Time of identification response.
6. CID net reports by operator.
7. Correctness of identification response.
8. Changes in identification response.
9. Identification confirmation responses.
10. Identity of console.

(C) *Data Sources:* The ID responses that the system acts upon can be directly recorded; other events related to the identification process cannot be.

(C) *Data Recording System*

1. Time of Tentative Track entry (New Track or Late Detect QAB).
2. Time of Firm Track entry (Position Correction QAB).
3. Time of ID Close Control action (Sequence, ID, or Hook symbol QAB).
4. Time of identification response (ID QAB).
5. Nature of identification response (ID QAB).
6. Changes in identification response (ID QAB).
7. Console responding.

(C) *Observer Recording*

1. Target type and characteristics.

2. CID net communications (from Comm Log).

3. Confirmation responses (by TRK SUP, SWC, FWC).

4. ID and other operator roles and behavior in the identification process.

(C) *Interview*

1. Ship's ID SOP and assigned roles of operators (FWC, SWC, TRK SUP, ID).

2. Adequacy of ID source data (FWC, SWC, TRK SUP, ID).

3. Value of CID report (FWC, SWC, TRK SUP, ID).

4. Identification decision criteria used (ID, SWC).

5. Identification decision behavior (ID, SWC).

6. Judgments of difficulty of identification task (ID, SWC).

(C) *Reduced Data Required*

1. Time between Tentative Track and identification responses (initial and final).

2. Time between Firm Track and identification responses (initial and final).

3. Correctness of identification response by target classification and category.

4. Time between track Close Control action and ID response.

5. Time between ID request for "outside" data and response.

6. Frequency of identification reviews by ID.

7. Frequency of changes in identification response by initiator of change (e.g., FWC fails to confirm ID response).

8. Scaling of ID source data measures of adequacy (confidence in identification response).

9. Scaling of identification behavior measures by identification criteria.

10. Scaling of identification task difficulty measures.

*Task 5: Select Target and Weapon*

(C) *Data Required:* The target and weapon selection performance of FWC, SWC, and IC.

1. Target type and characteristics.
2. Time of Firm Track entry.
3. Time of ID response entry.
4. Time of track Close Control entry.
5. Position of target by system events.
6. Position of weapon by system events.
7. Position of other targets and weapons by system events.
8. Distance traveled by target between events.
9. Type of weapons available.
10. Intelligence data available.
11. Target and weapon selection behavior by operator.
12. Consoles participating.

(C) *Data Sources:* The critical decision behaviors in target and weapon selection cannot be directly recorded or observed--only the resulting response.

1. Data Recording System.
    a. Time of Firm Track entry (Position Correction QAB).
    b. Time of ID entry (ID QAB).
    c. Time of track Close Control entry (Hook and Track Review QABs).
    d. Time of Target Selection (Hook and Engage QABs).
    e. Time of weapon selection (Ball Tab and Engage QABs).

f. Position of Target (Ball Tab x-y position and Position Correction QAB).

g. Position of weapon (Position of Target [Ball Tab x-y position and Position Correction QAB]).

h. Positions of other targets and weapons (Position of Target [Ball Tab x-y position and Position Correction QAB]).

i. Distance traveled by target (Ball Tab x-y position and QAB actions).

j. Identity of consoles.

2. Observer Recording.

a. Target type and characteristics.

b. Weapons available.

c. Intelligence data available.

e. Operator overt behavior (from Comm Log and direct observation).

3. Interview

a. Decision criteria used for target selection (FWC, SWC).

b. Decision behavior in selecting target (FWC, SWC).

c. Decision criteria used for weapon selection (FWC, SWC, IC).

d. Decision behavior in selecting weapon (FWC, SWC, IC).

e. Decision behavior times for events occurring between overt responses (FWC, SWC, IC).

f. Judgments of adequacy of data sources for target and weapon selection (FWC, SWC, IC).

g. Identification of information required but not available (FWC, SWC, IC).

h. Judgments of difficulty of the target and weapon selection tasks (FWC, SWC, IC).

i. Judgments of performance of target and weapon selection tasks by operator (FWC, SWC, IC).

(C) *Reduced Data Required*

1. Times between Firm Track entry and target and weapon selections.

2. Times between Close Control and target and weapon selections.

3. Times between ID response entry and targets and weapons selections.

4. Range of target from own-ship or Vital Area.

5. Range between target and weapon selected.

6. Ranges of other weapons from target.

7. Frequency of changes in target and weapon selections.

8. Frequency of previous target and weapons selections for engagement.

9. Frequency of required data unavailability.

10. Scaling of target and weapon selection decision behavior measures by decision criteria.

11. Scaling of target and weapon selection performance measures by operator.

12. Scaling of target and weapon selection task difficulty measures by operator.

*Task 6: Conduct Engagement*

(C) *Data Required:* The performance of FWC, SWC, IC and other operators in conducting an engagement after target and weapon selection.

1. Target type and characteristics.
2. Weapon type and characteristics.
3. Time of Firm Track entry.
4. Time of ID response entry.
5. Times of target and weapon selection.
6. Positions of target and weapon.
7. Time of initiation of engagement entry.
8. Time of completion of engagement.
9. Target weapon release point.
10. Success of engagement.
11. Subsequent weapon assignment.
12. Positions of other targets.
13. Conduct engagement behavior, by operator.
14. Consoles participating.

(C) *Data Sources:* Much of the data required to evaluate the conduct engagement task can be directly recorded or observed.

1. Data Recording System.
    a. Time of Firm Track entry (Position Correction QAB).
    b. Time of ID response entry (ID QAB).
    c. Times of target and weapon selections (Hook, Ball Tab, and Engage QABs).
    d. Time of Engagement entry (Engage QABs).

e. Time of completion of engagement (Cannot Comply QAB or weapon reassign QAB actions).

f. Positions of target and weapon (Ball Tab x-y position and Position Correction QAB).

g. Positions of other targets (Positions of target and weapon [Ball Tab x-y position and Position Correction QAB]).

h. Subsequent weapon assignment (Hook, Ball Tab, and Engage QABs).

i. Acceptance of engagement (Cannot Comply or Engage QAB).

j. Identity of consoles.

2. Observer Recording

a. Target type and characteristics.

b. Target weapon release point.

c. Weapon type and characteristics.

d. Success of engagement.

e. Operator overt behavior (from Comm Log and direct observation).

3. Interview

a. Reasons for non-acceptance of engagements (SWC, IC).

b. Decision criteria for conducting engagements (FWC, SWC, IC).

c. Decision behavior in conducting engagements (FWC, SWC, IC).

d. Reasons for successful and unsuccessful engagments (FWC, SWC, IC).

e. Judgments of performance in conducting engagements by operator (FWC, SWC).

f. Judgments of difficulty of the engagement task (FWC, SWC, IC).

(C) *Reduced Data Required*

1. Time between Firm Track entry and conduct engagement initiation and completion of engagement.

2. Time between ID response entry and conduct engagement initiation.

3. Time between conduct engagement initiation and completion of engagement.

4. Frequency of Cannot Comply responses by reasons.

5. Frequencies of successful and unsuccessful engagements.

6. Ranges of target at initiation and completion of engagements.

7. Scaling of decision behavior measures by decision criteria.

8. Scaling of conduct engagement performance measures by operator.

9. Scaling of conduct engagement task differently by operator.

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*Mission-Support Tasks*

(C) The six tasks discussed on the preceding pages can be referred to as "main-thread" tasks; that is, they are tasks concerned with the primary mission of the NTDS system: detecting targets, identifying them, keeping track of them, deciding what to do about them, and taking some appropriate action. But there are a number of other tasks that must be accomplished if the primary mission is to be successful. These can be referred to as "mission-support" tasks. Many of these tasks are performed by the TRK SUP, probably the operator who has the heaviest task load. Three of the TRK SUP mission-support tasks are discussed below: Geographic Positioning, Gridlock, and Track Supervision.

(C) Data is required to determine the importance of these mission-support tasks, the frequency with which they are performed, the amount of time required to perform them and, perhaps most important, to attempt to establish performance standards for the tasks in terms of system or mission requirements. The common characteristics of these tasks are that they occur aperiodically and that they are, for the most part, operator initiated; the system does not normally provide a direct indication of when these tasks should be performed. Another common characteristic of the system support tasks *may* be that they are independent of one another and of the mission-related activity level.

(C) *Mission-Support Task 1: Geographic Positioning.* The main data requirements include the accuracy with which ownship's true geographic position is fixed, the "acceptable" navigation error, the error required to elicit a navigation correction response from the TRK SUP, the frequency with which navigation position is checked for accuracy, and the relative merits of "automatic real-time navigation" procedures and the manual, or traditional, navigation procedures.

(C) The required data is available and can be readily obtained when own-ship is within radar range of land. There is no known method of verifying navigation accuracy when own-ship is beyond radar range of land.

(C) The following procedures are used in Geographic Positioning. The Position of Intended Movement (PIM) symbol is used to mark navigation points when the "real-time" navigation procedure is used. To enable the Data Recording System (DRS) to record navigation information, it is necessary to identify the "PIM tracks" being used as navigation points. PIM may either be entered by GPFC or by navigation keyset entry. The determination of whether a PIM track is being used to mark PIM or to mark a navigation position is somewhat equivocal. Any track for which the following sequence of actions is taken by SWC or TRK SUP will be tentatively identified as a PIM symbol being used as a navigation point marker: Hook, Ball Tab Enable, enter Mode, and enter the QAB or GPFC for Reference Point.

(C) Normally, three or more navigation points are used to fix own-ship's position; therefore, the above sequence of actions will occur three or more times (other actions, not related to navigation, may occur between each sequence). Following the third (or last) repetition of the sequence, the following sequence of actions will occur (regardless of whether PIM was entered at the navigation keyset or by GPFC entry): the SWC or TRK SUP will Hook one of the PIM symbols, enable the Ball Tab, and enter the GPFC for Geographic Reposition (this latter sequence may be repeated one or more times).

(C) Once the PIM symbols have been entered and identified as navigation point markers, it will be possible to obtain data on navigation accuracy. This will be accomplished by noting the initial and final position of the Ball Tab whenever the following sequence of actions occur: Hook one of

the PIM symbols, enable Ball Tab, enter GPFC for Geographic Reposition. The displacement (in range and bearing) between the initial and final ball tab position is equivalent to navigation error.

(C) Not all ships use the real-time navigation procedure. When it is not being used by ship's company, it will be necessary to have an observer, stationed at a console, who would use the procedure to determine and record navigation errors.

(C) The following reduced data will be required to evaluate the Geographic Positioning task:

1. The number of ships that use the "automatic real-time navigation" procedure and the number that do not.

2. The accuracy of navigation using the automatic real-time navigation as compared to manual navigation.

3. The average size of navigation error required to elicit a navigation correction response from SWC or TRK SUP when own-ship is within (tentatively) 10 miles of land, 11-20 miles, 21-30 miles, 31 miles to the limit of radar land fall, and when own-ship is beyond radar range of land.

4. The relationship between navigation error and gridlock error (see gridlock data requirement).

(C) *Mission-Support Task 2: Gridlock.* The main data requirements include the accuracy with which gridlock is maintained, the "acceptable" gridlock error, the gridlock error required to elicit a correction response from TRK SUP, the frequency with which the accuracy of gridlock is checked, the number of mutual tracks required to maintain a satisfactory gridlock, the effect on gridlock accuracy of variable range separation between Participating Units (PUs), the effect of multiple PUs, 2, 3, 4...n, on gridlock, the status of track correlation before own-ship enters the data link, and the time required to establish or check gridlock.

(C) All the data required to evaluate Gridlock performance can be obtained by the DRS. The DRS will record the initial and final x-y positions of the Ball Tab whenever it is enabled following D/A REM during the following sequence of actions: Hook (mutual track), D/A REM, enable Ball Tab, enter GPFC for Manual Gridlock. The Ball Tab will be rolled from the center of the Hook symbol to the remote position of the mutual track--this distance determines the magnitude of gridlock error.

(C) The following reduced data will be required to evaluate the Gridlock task:

1. The magnitude of gridlock error by:

    a. Time.

    b. Total number of system tracks.

    c. The number of unknown and hostile system tracks.

    d. The number of PUs.

    e. The distance between own-ship and the Gridlock Reference Ship (GRS).

    f. Whether GRS is held by own-ship's surface-search radar or other PUs.

    g. The number of mutual tracks between own-ship and the GRS.

2. The frequency with which gridlock is checked; that is, the frequency with which TRK SUP uses the D/A REM QAB.

3. The number of times that track correlation is attempted prior to entering an established data link net and the number of times it is not. Track correlation will be said to have been attempted whenever the following sequence of button actions occur: Clear Gridlock Pads, GPFC, Hook (remote track), Ball Tab (video), Manual Gridlock GPFC, D/A REM, Hook (remote track), Position Correction (remote track), Hook (local track), Drop (local track). This procedure is known as taking remote tracks into local stores. The

actions following Clear Gridlock Pads may be repeated several times in succession, once for each remote track taken into local stores.

4. The time required to establish gridlock; that is, the elapsed time between Clear Pads and the final Drop local track actions.

5. The time required to check gridlock; that is, the elapsed time between initiation and completion of the D/A REM function.

(C) *Mission-Support Task 3: Track Supervision.* The main data requirements include the frequency and duration of trouble tracks, the frequency and duration of track confusions, the accuracy of DET/TRK performance, and the supervisory behavior of the TRK SUP.

(C) Data on the frequency and duration of trouble tracks can be obtained by the DRS. The DRS will record the elapsed times between Position Corrections on each track: whenever the elapsed time between Position Corrections on a particular track exceeds 72 seconds, a trouble track condition exists.

(C) It is expected that analyses of the x-y plots of given situations will reveal most, if not all, incidents of track confusion. For example, perhaps the most troublesome track confusion is dual designation (different track numbers assigned to the same track). If the dual designation is detected by the TRK SUP, an x-y plot would show a "track fragment"; that is, a track was entered, was retained in the system for a while, and then was dropped for no apparent reason. If the Drop Track action is taken soon after a gridlock check or correction, this would tend to confirm that the dropped track had indeed been a bogus or invalid track resulting from gridlock error, the most common cause of dual designations.

(C) Other indications of the supervisory behavior of the TRK SUP can be recorded by the DRS. For example, the frequency of Track History requests by the TRK SUP for each

DET/TRK under his control would indicate both the level of supervision of DET/TRKs and the need for it. An observer could directly observe the TRK SUP and monitor his communications. Judgments of DET/TRK detecting and tracking performance and of TRK SUP supervisory performance and task difficulty may be obtained. The Track Supervision task is an important one; how well it is performed will likely significantly affect overall mission performance effectiveness.

(C) The following reduced data will be required to evaluate the Track Supervision task:

1. Annotated x-y track plot by situations.
2. Frequency of trouble tracks.
3. Time to eliminate trouble tracks.
4. Frequency of track confusions by type of confusion.
5. Time to resolve track confusion.
6. Frequency of Track History requests by operator.
7. Scaling of DET/TRK and TRK SUP performance measures.
8. Scaling of Track Supervision task difficulty measures.

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NTDS Documentation Reviewed

1. NWP 32 Anti-Air Warfare

2. NTDS Command and Staff Manual (M-5008)--FCPCLANT 71-0269

3. Program Operation for Model III, Phase 1 (Pacific) Operational Programs PD-6072 Vol. II (INPUT Operators Manual)

4. Program Operation for Model III, Phase 1 (Pacific) Operational Programs PD-6072 Vol. III (USER Operators Manual)

5. Student Manual for FAAWTC course K-2G-1010 (NTDS USER)

6. COMFIRSTFLT, Track Coordinators Handbook for TDS Link 11 Operators

# APPENDIX A

## SELECTED NTDS GLOSSARY

All paragraphs
in this Appendix
are classified CONFIDENTIAL

# SELECTED NTDS GLOSSARY

Airborne Tactical Data System (ATDS)

An automated tactical data system, installed in aircraft, capable of exchanging data, via Link-11, with other Tactical Data Systems. ATDS-equipped aircraft are used in Airborne Early Warning operations, and are also capable of intercept control by voice radio or Link-4A.

Alert

Console alerts are any event or condition brought to the attention of console operators by means of visual or audible warnings.

Ball Tab

1. A small circular symbol, 1/8" in diameter, used by the operator to designate position on PPI scope and to the computer.

2. As an action, Ball Tab is the means by which the operator can designate position on the PPI to the computer program. The Ball Tab is "rolled" to the desired location by use of the Track Ball.

Break Engage

1. An order to stop an engagement between a particular weapon and a particular target.

2. The alert generated by the above action.

CANTCO (CANNOT COMPLY)

1. A Link-11 message initiated by function code action by SWC in response to a Flag Order informing FWC that SWC is unable to carry out the Flag Order; also the alert generated at the FWC console by receipt of CANTCO from SWC.

Cease Fire

1. An order to stop firing all weapons at a particular target.

2. The alert generated by the above action.

Central Track Stores Locator (CTSL)

A number used by own-ship's computer for referencing local tracks. CTSL is the track number displayed at an operator console if no System Track Number has been assigned.

Close Control

Any symbol displayed within the Hook symbol, and thus designated by the computer program, is said to be in "close control." Operators can only take action on tracks in close control.

Combat Air Patrol (CAP)

Aircraft, usually fighters, used to protect a force from enemy air attack. The CAP also conducts search operations, acts as a radio relay, investigates contacts, and makes weather observations.

Combat Air Patrol Station

The designated position for CAP, which may be relative to a force or an objective area.

Combat Information/Detection Net (CID)

A voice radio net used for combat information and detection reporting among ships.

Data Link Reference Point (DLRP)

A fixed geographic point used to mark the origin of the reporting grid.

Data Readout (DRO)

A matrix of display windows used to provide amplifying information pertinent to the track in close control.

Detector (DET)

This operator performs a search function and enters new tracks into the system. The DET tracks contacts until they become firm track. This mode is infrequently used in the Fleet today. The function of DET and Tracker have been combined into a single task.

Dynamic Modular Replacement (DMR)

A modular programming concept which allows modification of an NTDS operational program while it is running.

DRO

Data Readout

Engage

1. With respect to missiles, or other surface-launched weapons, this is an order to engage the target with intent to destroy it.

2. With respect to interceptors or other airborne weapon systems, it is the order to commence attack on a target.

3. In the past tense, engaged is interpreted to be that point in the engagement process where:

    a. *Missiles:* The system is tracking, locked-on, and the order to fire has been given.

    b. *Airborne Systems:* Initial vector has been given, and orders to conduct the engagement have been issued.

FCSC

Fire Control System Coordinator. Though a member of the weapons direction team, the FCSC operates an NTDS-like

console. FCSC acts as an interface between CIC and weapons control.

Firm Track

1. An established track.

2. A tentative track becomes firm when it has been updated 3 times or just once if the track was initially entered as a Late Detect.

3. Firm track symbology is displayed on all own-ship consoles and is transmitted over the data link.

Flag Order

1. A Link-11 message initiated by FWC when directing weapons assignments/engagements of force units.

2. Also the alert generated at SWC Console upon receipt of FWC Flag Order message.

Force Weapon Coordinator (FWC)

The Force Weapon Coordinator is responsible for the review and evaluation of the overall tactical situation, and for the coordination of combined force weapons to achieve the most effective force defense.

General Purpose Function Code (GPFC)

A series of codes used to supplement the Quick Action Buttons. They are used to enter data or to provide special system capabilities, not normally required as often as those controlled by the QABs.

Gridlock

The process of referencing P.U.'s and consequently their track reports to a common reference point within a grid system.

Hook

1. A circular symbol, 1/2" in diameter, used by the

computer to designate tracks to the operator on the PPI.

2. As an action, Hook is a means by which the operator can place a particular track in Close Control.

Identification (ID)

The operator responsible for establishing identity, category, and class of all tracks in own-ship's area of surveillance responsibility. Also the procedures used to identify tracks.

Intercept Controller (IC)

The Intercept Controller directs the flight of interceptor aircraft, on both intercept and non-intercept missions. He is responsible to the Ship Weapon Coordinator (SWC) for the effectiveness of intercepts.

Interceptor

An aircraft, usually a fighter, used to intercept (identify or destroy) assigned targets.

Late Detection

A track which, when detected is close enough to own-ship to warrant immediate attention. Any track initially detected and entered in the system within some arbitrary distance from own-ship (usually 50 or 60 miles) is automatically considered a Late Detect. Any track, at any range, may be entered as a Late Detect by QAB action.

Link-4A

A UHF digital data communications link to provide automatic control of aircraft.

Link-11

A high-speed digital data communications link which provides automatic exchange of real-time tactical information between NTDS PUs.

Link-14

A teletype communication net used to provide semi-automatic, computer-controlled, one-way transmission of NTDS-evaluated track and status data from NTDS to non-NTDS units.

Local Track

Any track being tracked by own-ship.

Mutual Track

A track being tracked both locally and by another TDS unit.

Number Entry Dials or Keyboard

The dials or buttons on NTDS consoles used to select Function Codes or to enter data.

OTC

Officer in Tactical Command

Pairing

The assignment of a weapon to a target.

Pairing Line

A line displayed on a console PPI connecting a friendly track symbol (weapon system) and the symbol of the track (target) to which it is assigned.

Participating Unit (PU)

An NTDS unit participating in a Link-11 net.

Ping Pong

Radio net brevity code word for Link-11 communications. Used in conjunction with an adjective to describe the status of Link-11 operations.

Pointer

A communications symbol (one-half inch square) used by one console operator in conjunction with NTDS communications panel to direct the attention of another console operator to a position on his PPI.

Position Correction (POS CORR)

The process of updating track positions.

Quick Action Button (QAB)

QABs provide a means of rapid communication with the program; the function of these buttons is dependent upon the particular mode selected at a console.

Real Time

1. Pertaining to the actual time during which a physical process takes place.

2. Without degradation due to time delay.

Remote Track

Tracks reported to own-ship by other units by Link-11, but not held on own-ship's radars.

Reporting Responsibility

Reporting Responsibility for a given track is automatically assigned to the PU having the best Track Quality for that track.

Reposition

An action that moves a Hooked track to the location designated by the Ball Tab. This action does not constitute a track update.

Sequencing

An action which causes a console to sequence from one track to another. Also the QAB that accomplishes sequencing.

Selective Identification Feature (SIF)

A procedure and system used to identify specific friendly aircraft.

Ship Weapon Coordinator (SWC)

A mode of Data Utilization Display Console operation which provides the capabilities for carrying out Force Weapons Coordinator's orders. In addition, the operator is responsible for review and evaluation of own-ship's tactical situation and for the direction of own-ship's weapons.

Split

The separation of a single radar return into two or more tracks. Also the QAB used to enter Splits.

Symbol

An electronically generated shape displayed on the PPI to represent targets, interceptors, air tracks, surface tracks, or special points.

System Track

A track being reported or received over Link-11.

System Track Number (STN, TN)

A unique four-digit octal number used in NTDS data link communications to identify and reference each track in the system.

TDS

Tactical Data Systems

Tentative Track

A track that has been entered into the system but has not yet been updated a sufficient number of times to be a firm track. Denoted by Tentative Track Symbol which is presented only on INPUT consoles and is not transmitted over data link.

Track Ball

The device which controls the movement of the Ball Tab.

Track Category

In NTDS, the track categories are: Air, Surface, Subsurface, and Special Points.

Track Classification

In NTDS, the track classifications are: Airborne Early Warning, Anti-Submarine Warfare Aircraft, Interceptor, Strike Aircraft, Carrier, Missile ship, Picket (DD), Possible Submarine, Probable Submarine, Positive Submarine.

Tracker

Console operator who updates firm tracks. This function is typically combined with the DET task. An operator designated as a DET/TRK uses the tracker mode of console operation.

Track History

A series of the most recent updates of a track which may be displayed on a console PPI at the operator's request.

Track Quality

A numerical value, assigned to a track, computed from values related to the past tracking performance on the track. Track Quality is used in determining Link-11 Reporting Responsibility.

Track Supervisor (TRK SUP)

A mode of Data Input Display Console operation. The operator monitors and supervises the overall performance of all the NTDS INPUT functions.

Utility Mode

A mode of console operation that can be used by any

operator to temporarily add additional capabilities to those normally available to him. Typically an operator switches to the Utility Mode, performs a specific function, and then switches back to his original mode.

Vital Area

The area wherein the protected force is located. The size of the Vital Area is a function of number and disposition of units in the protected force and the capabilities of available force defensive weapons.

# APPENDIX B

## DETAILED TASK DESCRIPTIONS FOR SELECTED NTDS OPERATORS

All paragraphs in this Appendix are classified CONFIDENTIAL

## *FORCE WEAPONS COORDINATOR (FWC) TASK DESCRIPTION*

### *General*

The FWC acts for the Officer in Tactical Command (OTC) and is responsible to him for evaluation of the force tactical situation, and for the combat direction of force weapons. In contrast to conventional (non-NTDS) task groups where the OTC usually delegates the duty of Force AAW Commander to a subordinate commander, the NTDS OTC usually exercises this responsibility himself (through a senior member of his staff acting as FWC).

FWC is responsible for:

1. Determining the threat to the force of each target (all tracks not identified as confirmed friend are considered targets).

2. Selecting the most appropriate weapon(s) to counter each target.

3. Directing the force Ship Weapons Coordinator (SWC) to engage designated targets with selected weapon(s).

4. Ordering Break Engage and Cease Fire.

### *Detailed Task Description*

FWC selects targets for engagement on a threat basis. The most threatening targets are engaged first. FWC uses system computed threat values plus indications available from his PPI and DRO displays to select targets. Weapons assignments are made in conformance with the concept of Defense in Depth. Several lines of defense are established along the threat axis. For example, three lines of defense might consist of interceptors, long-range missiles, and short-range missiles. An attempt would be made to have each line of defense engage and destroy as many incoming targets as possible. In theory, each succeeding line of defense would have fewer and fewer targets to deal with.

FWC orders engagements by Hooking a target, Ball Tabbing

the desired weapon and pressing his Engage Interceptor or Engage Missile Quick Action Button (QAB). If a ship is controlling more than one interceptor, FWC may Ball Tab a specific interceptor or he may Ball Tab the ship and let the ship's SWC decide which interceptor to use.

In any event, when FWC presses an engagement QAB, a pairing line connecting the selected target and weapon and a Flag Order are transmitted via Link 11 to the ship controlling the selected weapon.

The SWC then issues the necessary orders to complete the engagement. If SWC is unable to comply with FWC's order he responds by entering the General Purpose Function Code (GPFC) for Cannot Comply. The Cannot Comply response would generate an alert at FWC's console and he would then select another weapon to engage the target.

FWC has QABs that can be used to order Cease Fire and Break Engage.

FWC observes the progress of engagements by monitoring his PPI and observing the changes in engagement symbology as they occur.

*SHIP WEAPONS COORDINATOR (SWC) TASK DESCRIPTION*

*General*

The SWC is responsible for the combat direction of own-ship's weapons. SWC directs engagements of own-ship's weapons either in response to the Force Weapons Coordinator's orders or on his own initiative. SWC continuously evaluates own-ship's tactical situation by observing the indications presented to him on his PPI and DRO displays.

Other SWC duties include supervising of the other NTDS operators and managing the configuration of own-ship's computer program.

*Detailed Task Description*

SWC's weapons direction task consists of two parts--target selection and weapon(s) selection. The weapons available to SWC are own-ship's missiles and interceptor aircraft, when assigned.

When multiple targets are present, SWC attempts to engage the most threatening target first. He would also like to engage the targets as far from own-ship as possible for two reasons: (1) to destroy the target before it reaches its weapon release point, and (2) to have a second shot at it if the target should survive the initial engagement. For both of these reasons, SWC would prefer to engage the target initially with interceptors.

The procedural aspects of the SWC's weapons direction task are straightforward. To engage a target with an interceptor he Hooks the selected target (places it in close control), Ball Tabs the interceptor, and presses the Engage Interceptor Quick Action Button (QAB). These actions generate a Target Assigned alert at the Intercept Control (IC) console.

To engage a target with own-ship's missiles, SWC Hooks the target and presses his Engage Missile QAB. These actions generate a Target Assigned alert at the Fire Control System Coordinator's (FCSC) console.

If the target can be engaged by the weapon selected, trial geometry is displayed on SWC's PPI and the DRO display indicates time-to-go-to-intercept. If the intercept is not possible, the DRO reads out Poor Situation. Assuming the intercept is possible, the SWC must decide whether to go ahead with it. For example, if an interceptor had been selected, the factors that would influence SWC's decision would be time-to-go, and proximity of intercept point to own-ship's missile envelope.

If the intercept could not be completed beyond ownship's missile envelope, SWC would probably decide to use missiles instead of the interceptor.

Ideally, all targets would be engaged before they entered the Vital Area. In any event, an attempt would be made to engage and destroy every target before it reached its Weapon Release Point (the drop point for a gravity bomb or the firing point for an Air-to-Surface Missile (ASM).

If an engagement is initiated but the SWC decides to abort it prior to its completion, he presses the Cease Fire or Break Engage QAB. Cease Fire is used to order *all* ownship's weapons to cease fire on the target in close control at the SWC console. Break Engage is used to order a particular weapon to cease fire.

*Supervision of Other Operators*

For the most part, SWC's supervision of the other NTDS operations is management by exception. He gets directly involved only when he observes unsatisfactory performance.

The frequency with which he is required to intervene varies considerably depending on his experience and proficiency, the experience and profiency of the other operators, and the tactical situation.

*Management of the DMR*

Dynamic Modular Replacement (DMR) is a relatively new concept in NTDS programming. DMR is designed to provide NTDS with a better capability to handle the task at hand while sacrificing, momentarily, some system flexibility.

The DMR consists of a Resident Module and several Transient Modules. The Resident Module is the basic NTDS operating program and remains in core at all times. The Transient Modules are designed to provide the system with special capabilities. The Transient Modules can be added or deleted while the program is running.

The following is a list of the Transient Modules.

TRANSIENT MODULES

| | Name | Number | Version | Size (# Cells) |
|---|---|---|---|---|
| 1. | Height Size (HSA) | 10 | 1 | 2290 |
| 2. | Intercept Control (IC) | 14 | 0 | 4824 |
| 3. | Intercept Control (ICA) | 14 | 1 | 3764 |
| 4. | Intercept Vectoring (IV) | 14 | 2 | 3289 |
| 5. | Electronic Warfare (EW) | 15 | 0 | 2395 |
| 6. | Electronic Warfare (EWA) | 15 | 1 | 2565 |
| 7. | Surface Maneuvering (SM) | 16 | 0 | 1551 |
| 8. | Link 14 (BL) | 25 | 0 | 2471 |
| 9. | Link 4A (LF) | 26 | 0 | 1103 |
| 10. | Training (TB) | 35 | 0 | 3439 |
| 11. | Aircraft Data Entry (AE) | 36 | 0 | 0234 |
| 12. | Mark 11 (MEC) | 50 | 0 | 5752 |

Transient Modules are added or deleted by General Purpose Function Code (GPFC) entry. The present status of the DMR can be called up and displayed on the Data Readout (DRO). Modules are added and deleted so as to match system capabilities with the requirements of the existing operational situation.

*INTERCEPT CONTROLLER (IC) TASK DESCRIPTION*

*General*

The IC's primary responsibility is to control aircraft on intercept and other type missions. Usually the IC acts in response to SWC orders but may act on his own initiative to counter an immediate threat.

During normal Anti-Air Warfare (AAW) operations, interceptors will be assigned to Combat Air Patrol (CAP) stations

usually located in advance of the task group along the threat axis. When an incoming raid (one or more hostile aircraft) is detected, the Force Weapons Coordinator (FWC) will designate which targets are to be engaged by which weapons. His decision will be transmitted to Participating Units (PU) via Link 11 in the form of engagement Flag Orders. The SWC(s) acting either in response to such an FWC order or on his own initiative will select an own-ship weapon to engage each target in his zone of responsibility. If he decides to engage a target with an interceptor, he will press his Engage Interceptor Quick Action Button (QAB), thus sending a Target Assigned Alert to the air controller controlling the particular interceptor to be used in the intercept.

*Detailed Task Description*

The IC responds to the Target Assigned Alert by pressing his Sequence QAB. This places his interceptor in close control and a pairing line is displayed on his PPI connecting his interceptor and the designated target.

The IC presses the QAB appropriate for a Pursuit or Collision intercept. This action calls up *trial geometry* for the desired type of intercept. The IC attempts to complete the intercept as expeditiously as possible and as far from own-ship or Vital Area as possible. With these objectives in mind, the IC selects the geometry he considers best on the basis of time-to-go-to-intercept, and the distance of the point of intercept from own-ship or the Vital Area. As soon as the IC has made his choice and sent his first control order to the interceptor (via voice radio), he presses Order Sent. The Order Sent button action causes a change in the engagement symbology which is transmitted over the data link to inform FWC and all PUs that the target is being engaged.

If the interceptor is equipped with a Link 4A receiver, a device designed to permit air control orders to be sent to

the aircraft via digital data link, course, speed, and altitude orders *are initiated* by the Order Sent button action.

The air controller reevaluates the intercept and sends "bogie dope" (range and bearing of target from interceptor) to the aircraft every 10 seconds (once every radar sweep). On each sweep of the radar, the IC Position Corrects (tracks) his interceptor and the target. He checks to ensure that the interceptor is flying the ordered course (by comparing the position of the interceptor symbol, which is being dead reckoned at ordered course and speed, and the position of the interceptor's video).

During an intercept, the IC has, in essence, two sequential tasks to perform. These might be called course and precision control. During course control, the first task, the IC is concerned with directing the interceptor into the vicinity of the target. To do this, the IC must insure that target bearing (from the interceptor) remains steady and that the range between interceptor and target is decreasing.

The intercept may be complicated by target maneuvers, strong winds, obstacles such as mountain tops, or enemy fighter escorts. The IC must be alert to compensate for or to minimize the effects of these factors.

During the final or precision phase of an intercept, the air controller seeks to ensure that his interceptor will be in the appropriate final position relative to the target. The exact parameters of the final position vary as a function of the characteristics of the Air to Air Missiles (AAM) carried by the interceptor but are always astern and below the target. All intercepts become tail chase or pursuit intercepts in their final stages because of the requirement to release interceptor weapons from astern of the target.

When the intercept is completed, or if it is broken off before completion, the IC presses the Cannot Engage QAB which

notifies the SWC that the interceptor is available for another assignment.

Assuming other hostile targets are present, SWC may immediately assign another target to the IC or the IC may commence a new intercept on his own initiative in the absence of an SWC order. The subsequent target will be selected on the basis of its proximity to the interceptor and to the protected force.

*TRACK SUPERVISOR (TRK SUP) TASK DESCRIPTION*

*General*

The Track Supervisor monitors and supervises the performance of all own-ship Input operators. In addition, he is responsible for maintaining gridlock, monitoring the performance of Link 11 and 14, and acting as the Combat Information and Detection (CID) Net communicator. He also acts as a back-up for all other input operators.

*Detailed Task Description*

1. Designates mode and radar to be used by each input operator.

   a. The normal arrangement of mode and radar is not likely to change from watch to watch. The TRK SUP should, however, be cognizant of present radar performance, fade zones, inversion layers, etc., and should direct a change in range scale if existing conditions dictate.

   b. During a regular underway watch, the TRK SUP rotates the Input operators periodically from console to console (about every 30 minutes). Personnel are rotated infrequently during General Quarters.

2. Assigns search sectors to Detector/Trackers (DET/TRK)

   The search sectors are likely to be the same from watch to watch and day to day. However, if there is a lot of activity in one sector and not in another, the TRK SUP may assign targets in the loaded sector to a DET/TRK who is not as busy.

3. Supervises the performance of DET/TRK. The TRK SUP is charged with monitoring the performance of the DET/TRK.

   a. To do so, the TRK SUP keeps own-ship centered on his PPI. The PPI scope and the Data Readout (DRO) provide several indications of TRKer performance.

      (1) The TRK SUP can obtain an overview of the tracking situation by scanning his PPI to determine whether each piece of video has been assigned a symbol and to check the relationship of the track symbols to target video. The symbols and video should be continuously superimposed on one another and should be moving together.

      (2) Another indication used by TRK SUP to check on tracking performance is Track Quality (TQ). Track Quality is a numerical value (from 1 to 7) assigned to each track, computed from values relating to past tracking performance. TRK SUP should insist on a TQ of 5 or better on each track.

      (3) The TRK SUP also uses the track history function to monitor tracker performance. Track history is a display of the position of the ball tab for the 5 most recent track updates. The ball tab positions should form either a straight line or a smooth curve and should be about equally spaced.

4. Assists DET/TRK by entering new tracks, updating tracks, and entering splits.

   a. The TRK SUP should refrain from tracking as much as possible. The more time the TRK SUP spends tracking, the less time he has available to attend to his supervisory tasks.

5. Drop tracks when necessary.

   a. Tracks are dropped when they go beyond radar range, or if they represent downed aircraft, or if they represent bogus or invalid tracks.

6. Uses IFF to assist in tracking.

   a. IFF is usually used in tracking at the request of a DET/TRK to help in resolving the identity of merged or interchanged tracks.

7. CID net communications.

   a. The amount of time the TRK SUP spends on the CID net varies as a function of the tactical situation and the number of non-NTDS ships in the Task Group.

   b. An initial detection report is made via the CID net for every target (this report serves as back-up for the automatic Link 11 report).

*Monitor*

An appreciation of the monitoring tasks performed by the various NTDS operators is central to an understanding of the real world of NTDS. NTDS operators refer to the philosophy underlying the NTDS monitor task as *check-check-check*, i.e., every operator checks on the performance of every other operator. To illustrate, the primary responsibility for detecting new video rests with the DET/TRK but every operator assists in the search task and any operator may enter a new track; the primary responsibility for selecting targets and assigning weapons rests with the FWC, but SWC or IC may initiate engagements in the absence of FWC action. In the search task, upper echelon operators are checking on the performance of the lowest echelon performer; in the weapons assignment task, lower echelon operators are checking on the performance of a higher echelon performer.

In addition to the monitoring tasks performed by the operators, the computer is also constantly checking performance; it rejects certain operator actions, reminds operators to perform some overdue actions, alerts operators to special situations, and makes available data useful for checking on past performance.

The Input operator with the largest monitoring load is the TRK SUP. The TRK SUP's primary responsibilities are (1) insuring the Input operators are performing satisfactorily, and (2) insuring that the data transmitted over the data link is accurate and properly referenced.

The TRK SUP monitors the performance of the Input operators by periodically reviewing system tracks, as described in 3a above.

The TRK SUP must also be alert to detect *confused tracking situations*. Confused tracking situations may result from (1) invalid tracks (track symbol not associated with a valid piece of video); (2) dual designations (two track numbers associated with the same piece of video); (3) duplicate tracks (two valid pieces of video with the same track number); (4) failure to hand over tracking responsibility (a necessary, manual action required whenever a track fades from own-ship's radar but is still held on another Participating Unit's (PU) radar; failure to hand over tracking responsibility will eventually result in a runaway track); (5) decorrelation (occurs when the discrepancy between local and remote reported position of a system track exceeds the limit prescribed by the program; decorrelation will result in a dual designation and perhaps a runaway track); (6) interchanges (when tracks cross, particularly if the tracks are on nearly parallel courses, the system has a tendency to exchange track numbers between the two tracks); (7) merges (occur when two formerly separate tracks merge into a single track); (8) splits (occur when a single track, consisting of two or more aircraft flying in formation, divide and become two or more tracks). To prevent or correct confused tracking situations, the TRK SUP must take corrective action in a timely manner.

Another of the TRK SUP's major monitoring tasks is ensuring that the data transmitted over Link 11 is accurate and properly referenced. This task includes ensuring that own-ship's data link terminal is operating correctly, and that a satisfactory gridlock is being maintained.

The System Monitoring Panel, operated by the SWC, is designed to detect *failures* of the data link. The TRK SUP by observing the indications available from the Data Link

Remote Unit, the Audio Monitor, and his PPI may be able to detect an *impending failure* of the data link.

The TRK SUP's task is to combine, analyze, and interpret the available indications and to take corrective action when it is called for.

The amount of time required to perform this monitoring task and, indeed, the value of performing it are unknown. At least on some ships, TRK SUP is advised to ignore or pay very little attention to this task. On other ships, this is considered to be among the TRK SUP's most important tasks. No data is at present available to verify whether either of these positions is correct.

*Gridlock*

When two or more NTDS ships are operating together they exchange tactical data via a digital data link--Link 11. An x-y grid coordinate system is used to report/exchange track position information. An arbitrary, geographic position is selected as the reference point or origin of the grid. This reference point is referred to as the Data Link Reference Point (DLRP).

Before tactical data is exchanged between units, each unit determines its position in relation to DLRP. As a result of the appropriate operator button actions, this relationship is entered into the computer as a mathematical constant which is used in converting the range and bearing information obtained by own-ship's sensors into x-y grid coordinate position information. It is this grid coordinate data that is exchanged among units via the data link.

If a unit makes an error in determining its relationship to DLRP, there will be an equivalent error in the track position information it reports. Such an error is referred to as a gridlock error, i.e., own-ship's grid does not originate at, "is not locked to," DLRP.

The following diagram illustrates a gridlock error.

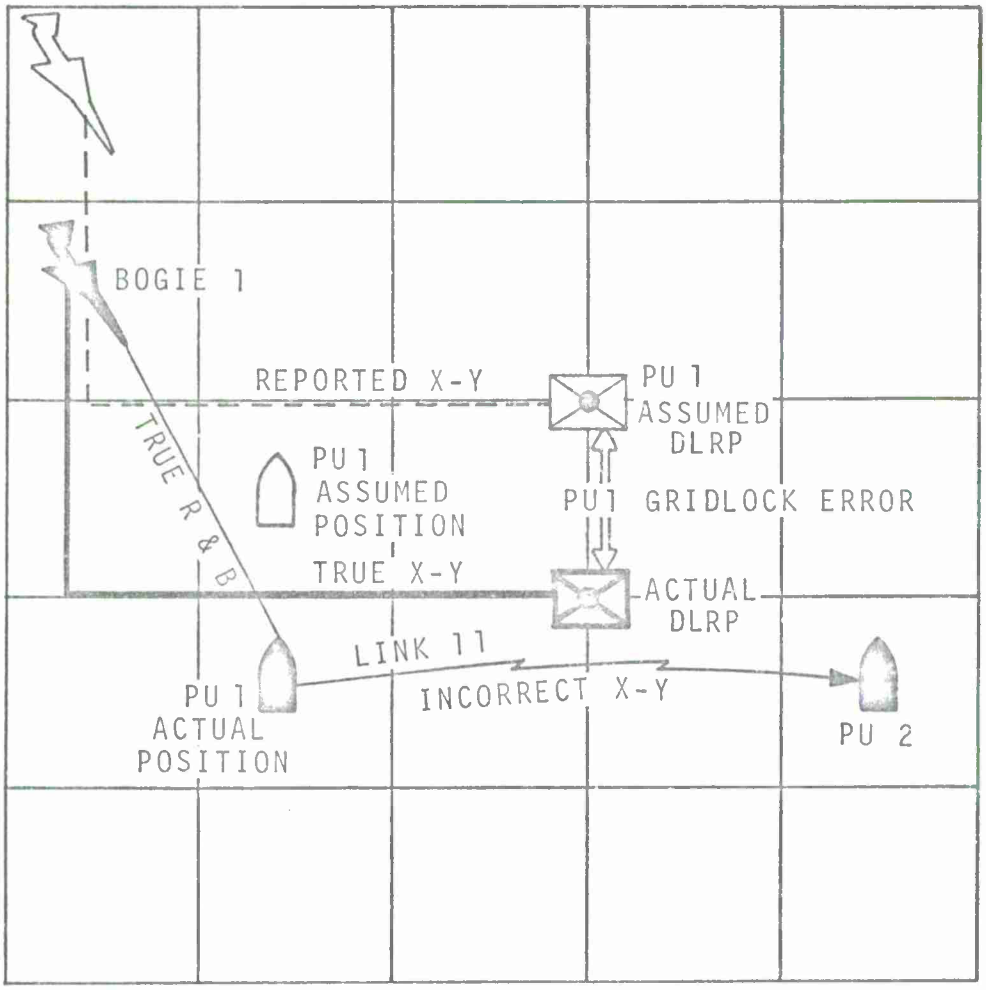


DIAGRAM OF GRIDLOCK ERROR

1. PU1 holds Bogie 1 on its radar, but Bogie 1 is beyond the PU2's radar range.

2. Bogie 1's true x-y grid position is 2-1/2 west and 2-1/2 north. Due to gridlock error, however, PU1 is reporting Bogie 1's position as 2-1/2 west and 3-1/2 north.

3. Depending on the size of PU1's gridlock error, which may be only a few thousand yards or as much as tens of miles, the track position data being reported by PU1 to PU2 may be satisfactory, useless, or misleading.

It should be noted that the gridlock error would not affect PU1's ability to engage Bogie 1. Each engagement of

a target by an individual ship is conducted using that ship's sensor information.

In the diagram, PU2 is assumed to have a good gridlock. In reality, of course, PU2 could also be out of gridlock. If this were so, PU2's gridlock error would probably compound the error in the reported position of Bogie 1, although it is conceivable that PU2's error could cancel PU1's error. The significant point is that each unit in a task group may have incorrectly calculated its relationship to DLRP. That is, for example, if there were 10 ships in a task group, it is conceivable each could be out of gridlock and each could be reporting erroneous or conflicting data.

The diagram depicts one of the key advantages of NTDS over conventional CIC's, namely the capability of NTDS to display the real-time position of remote tracks. A remote track is one held on one PU's radar but not on another PU's radar. (A mutual track is one held by both PU's.) When a significant gridlock error exists, the advantage of the remote track reporting capability may be lost or even prove detrimental if it causes excessive track confusion.

Dual designation is an example of track confusion. A dual designation exists when two or more track numbers are assigned to a single target. The most common cause of dual designations is gridlock error. Assume Ship A is tracking Aircraft A. Ship A is reporting the position of Aircraft A to Ship B which does not hold Aircraft A on its radar. Further assume that a significant gridlock error exists, either Ship A or Ship B or both are significantly out of gridlock. Aircraft A is on a course that will take it into Ship B's radar range. When Ship B finally detects Aircraft A, a check will be made to determine if a track symbol and a track number have previously been assigned to it. Under ideal conditions, which include a perfect gridlock, when Ship B detects Aircraft A, the track symbol previously assigned to it by Ship A

will be superimposed on the video detected by Ship B. In this instance, however, the ships are not in good gridlock, therefore the symbol will not be superimposed on the video.

At this point it is up to the DET/TRK or the TRK SUP on Ship B to decide whether the new piece of video is Aircraft A or a different aircraft. If the new piece of video and the track symbol for Aircraft A are close to one another and the new piece of video and the symbol are on about the same course and speed, the decision is likely to be that the new piece of video is, in fact, Aircraft A. If the symbol and the new video are not close to one another, the decision is likely to be that the new piece of video is not Aircraft A. Thus the "new" piece of video will be entered into the system as a new track. We now have two track symbols assigned to a single aircraft.

With just two ships and only one aircraft involved, dual designation is perhaps not a serious problem. It is, however, possible (even likely) that these two ships will assign two track symbols to every mutual track they hold until the gridlock error is resolved. It is also possible, even likely, that if three ships are significantly out of gridlock, three track symbols will be assigned to each mutual track. Obviously, if all these tracks were identified as hostile it would be difficult for the force level decision maker charged with the responsibility for assigning weapons to efficiently counter the threat posed by each of these "targets."

Actually this scenario should not be carried too far. Before long someone would realize something, probably gridlock, was wrong. Action would then be taken to correct gridlock and to resolve the track confusion.

Several questions arise. How long is "before long?" How likely is it that the type of track confusion described will occur at a crucial time? Earlier we spoke of a



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"significant gridlock error": how big is a significant gridlock error? We also referred to the DET/TRK or TRK SUP deciding whether he had one target or two based on whether the symbol and the video are close to one another. How close is close?

Unfortunately, although there is much conjecture about the answers to these questions, there are no answers. At least there do not seem to be any answers based on hard data.

The TRK SUP is responsible for establishing and maintaining gridlock. The procedures for doing so appear to be relatively simple and straightforward. Apparently this appearance is deceiving. Gridlock error is repeatedly mentioned as one of, if not, the most common and significant problems in NTDS task group operations.

The gridlocking task can be divided into three subtasks:

1. Fixing own-ship's true geographic position and thereby own-ship's position relative to DLRP.

2. Establishing gridlock.

3. Maintaining gridlock.

The procedural aspects of these tasks are adequately described in the NTDS documentation and are unlikely to be of much interest to the reader of this report. In any event, since the procedural aspects of gridlocking are fairly straightforward, the causes of the gridlock problem apparently lie elsewhere. The identification of those causes awaits the kind of detailed analysis that will only be possible when quantitative data become available.

## *IDENTIFICATION (ID) OPERATOR TASK DESCRIPTION*

### *General*

The ID operator is responsible for performing that portion of the identification task delegated to him by command and for

entering the identification of all tracks into the system. The identification of a given track is determined on the basis of (1) Identification Friend or Foe/Selected Identification Feature (IFF/SIF) information, (2) the track's course, speed, and altitude, (3) intelligence data, (4) the target's responses to ordered maneuvers, (5) current operation orders, and (6) orders received from the Officer in Tactical Command (OTC).

The ID operator (1) *identifies* targets as friend or foe, (2) determines track *categories* (air, surface, subsurface), and (3) assigns *class* designations (helo, destroyer, strike or interceptor, etc.).

The ID operator assigns an identification confidence level to each track: *unknown*, *assumed* friend or hostile, *confirmed* friend or hostile. The ID operator may (1) increase his confidence level, e.g., unknown-to-assumed-to confirmed; he may decrease his confidence level, e.g., confirmed-to-assumed (this action generates an ID Change alert); or he may change his identification, e.g., friend-to-hostile or hostile-to-friend (this action also generates an ID Change alert).

An ID conflict is said to exist when two NTDS Participating Units (PU) disagree on a track's identification. ID conflicts are resolved automatically by the computer (in favor of the source reporting the most positive information, e.g., confirmed in favor of assumed), manually by the participating units, or unconditionally by the force ID operator.

*Detailed Task Description*

1. Enter Mode and Radar

   a. Set Mode and Radar selector

   b. Depress Enter Mode and Radar QAB

2. Place targets in Close Control

   a. Depress Sequence QAB

   b. Hook symbol appears around highest priority target not presently in close control by another ID operator (target priority is computed automatically by the system, on a confidence level basis).

*ID Scenario*

1. ID operator is sequenced to an unidentified track. An Unident alert is displayed on his alert panel.

2. The "expected" action is for the ID operator to make an Identity or Class entry. He may clear the alert by pressing Sequence (ID not attempted) which will sequence him to another target, but since an unidentified track has a high sequencing priority, it will soon be placed in close control again. (ID doctrine specifies that the ID operator should enter Unknown rather than Sequence in this situation, and this is what he usually does.)

3. The ID operator attempts to identify tracks using IFF/SIF. He will do this by entering the Request Interrogation function code and then depressing the Function Code button. This causes the Beacon Video Processor to interrogate a position in space centered on the position of the hook symbol, i.e., to interrogate the track in close control.

   a. If the target is a friendly aircraft and if its IFF equipment is operating, a readout of the target's SIF codes (Modes 1, 2, and 3) will be presented on the UPA-50 display panel. This should be sufficient to positively identify a friendly aircraft provided its IFF equipment is operating properly. The SIF code displayed on the UPA-50 is entered on the number entry

panel and becomes permanently associated with the track and can be called up on the DRO whenever the track is placed in close control.

b. If an acceptable IFF response is not received, the ID operator will attempt to contact the aircraft by voice radio using an assumed or indefinite call sign.

If communications are established with a friendly aircraft and if its IFF is operable but was not turned on, the pilot will probably turn it on. (Under some circumstances, tactical constraints may prohibit the pilot from turning on his IFF gear.)

If communications are established with a pilot who claims to be friendly but states that his IFF is inoperative, he is told to respond to ordered maneuvers. In an actual hostile environment, the first order would be a heading change away from own-ship (or task group). Ordered maneuvers are prearranged turn patterns. For example, Ordered Maneuver Charlie might be a series of three 90° port turns followed by a 180° starboard turn. (It is not always advisable to use the ordered maneuver procedure. For example, a friendly strike aircraft returning from a mission may be low on fuel or damaged. In such a case, the pilot may refuse to execute the ordered maneuver.)

Friendly aircraft flying missions in a combat zone fly along prearranged flight paths. The ID operator draws flight paths and approach corridors on his scope (using his lines General Purpose Function Code [GPFC]) and checks to see

if an unidentified aircraft is generally conforming to the prearranged plan. Checkpoints can also be indicated (using Points GPFC).

c. If communications cannot be established with the unidentified aircraft, command may decide to lock-on it with a Fire Control radar or to check it out visually by having a CAP aircraft intercept it.

*ID Review*

The ID operator reviews the ID of each system track aperiodically. The time between reviews varies primarily as a function of the ID confidence level assigned to the track ID, e.g., assumed friend tracks are reviewed more often than confirmed friend tracks.

The procedures used during the ID review are similar to those used in initial ID.

## *DETECTOR/TRACKER (DET/TRK) TASK DESCRIPTION*

*General*

The primary responsibilities of the DET/TRK are to detect targets, enter new tracks into the system and to then maintain an accurate track on each track in his assigned sector of responsibility.

*Detailed Task Description*

*Initial Equipment Setup*

1. Enter Mode and Radar

    a. Set Mode and Radar selector

    b. Depress Enter Mode and Radar push button

2. Offset PPI display (if so directed)

    a. Roll Ball Tab to desired offset

b. Set the General Purpose Function Code (GPFC) for automatic offset

c. Press Function Code button

3. Set PPI range as directed

*Radar Search*

1. Conduct visual search of assigned sector

2. Detect video. Determine if a track number/symbol has already been assigned to the video.

   a. Generally, if a track has been previously entered, either by own-ship or another NTDS unit, a track symbol will be associated with the piece of video.

   b. It is possible, however, that the track may have been previously entered by another Participating Unit (PU) but due to a gridlock error, the video and the track symbol are apparently not associated with one another. (See Track Supervisor task description for a discussion of gridlock.)

*Enter Tentative Track*

1. Depress Enable Ball Tab Quick Action Button (QAB).

2. Use Track Ball to roll the Ball Tab symbol to video.

3. Align Ball Tab symbol with the center leading edge of video (by rolling Track Ball).

4. Depress New Track push button, tentative track symbol appears on the PPI display of all Input consoles.

5. After three updates, the New Track becomes a firm track and a firm track symbol appears on Input and User consoles and is transmitted via Link 11.

6. If 72 seconds elapse between updates of a tentative track, the track is automatically dropped by the system.

*Updating Firm Tracks*

1. Each firm track must be updated every 72 seconds or it becomes a trouble track. Trouble tracks are indicated by blinking track symbols. The blinking feature serves as a reminder to *all* operators that the track has not been updated recently. It does not *necessarily* mean that the track data for that track is unreliable.

2. The system automatically sequences to each track in turn. Automatic sequencing takes place in response to either a Sequence of Position Correction QAB action.

3. The system dynamically dead reckons track symbols to current video position, i.e., the symbols move with the video assuming the target does not maneuver radically.

4. The Hook symbol appears around the track symbol sequenced to. If the symbol dot (/.\) is aligned with the center leading edge of the video, the operator updates the track's position by pressing his Position Correction QAB. If the symbol dot is not properly aligned with the video, the operator enables the Ball Tab by pressing the Enable Ball Tab QAB. He then uses the Track Ball to roll the Ball Tab and align it with the center leading edge of the video. Again, the new position is entered by depressing the Position Correction button. Pressing the Position Correction QAB causes sequencing to occur.

5. The Detector/Tracker retains his search responsibility and is charged with searching for new targets no matter what his tracking load may be.

*Comment*

The "average" fleet operator reportedly can track not more than 6 to 10 targets simultaneously. Several factors limit the number of tracks a tracker can track. The most apparent limiting factor is the requirement to update each track every 72 seconds.

Reportedly, the most severe problem encountered by the tracker is monotony. Track updating is an easy, highly repetitive task. There was substantial agreement among the people we talked to that most trackers become ineffective and should be rotated about every 30 minutes.

The major cause of tracking error is reported to be the failure of the tracker to accurately align the ball tab to the center leading edge of the video. This problem seems to have been somewhat alleviated by the fleet introduction of the AN/SPS-48 (series) radar.

Other functions performed by the DET/TRKers are entering Late Detections and track Splits. These tasks are, however, in reality nothing more than special instances in the normal tracking situation.

One of the DET/TRK's more important tasks is to monitor his own past performance. Several indications permit him to do this. He can observe and compare the instantaneous and continuous positions of the video and the track symbol. They should be continuously superimposed on one another assuming the target maintains a fairly steady course and speed. By Function Code entry, the DET/TRK can call up a track history display. The track history consists of the Ball Tab positions for the five most recent updates. The Ball Tab positions should form either a straight line or a smooth curve and should be about equidistant. Yet another indication the DET/TRK can use to check on his past performance is Track Quality (TQ). Track Quality is displayed on the DRO as a number from 1-7, the higher the number, the better the track quality. The system computes track quality using several parameters such as time elapsed since last update, track smoothness, etc.

Through a judicious interpretation of these indications, the DET/TRK can keep himself apprised of his own performance.

If he is not performing adequately, the TRK SUP will

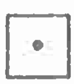
(should) take whatever action is necessary to ensure that his performance improves.

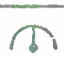
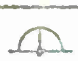
APPENDIX C

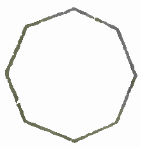
NTDS SYMBOLOGY

All information
in this Appendix
is classified CONFIDENTIAL

| SYMBOL | MEANING |
|---|---|
|  | Surface Friendly Track |
|  | Air Friendly Track |
|  | Subsurface Friendly Track |
|  | Surface Unknown Track |
|  | Air Unknown Track |
|  | Subsurface Unknown Track |
|  | Surface Hostile Track |
|  | Air Hostile Track |
|  | Subsurface Hostile Track |
|  | Ownship |
|  | Aircraft Carrier Friendly |
|  | Surface Hostile Engaged |
|  | Subsurface Hostile Engaged |
|  | Surface Friendly Engaged |
|  | CAP Station |
|  | Corridor |

| SYMBOL | MEANING |
|---|---|
|  | Formation Center (Utilization Console only) |
|  | Reference Point |
|  | Data Link Reference Point (Reference Point and Unknown Surface symbols) |
|  | ECM Fix |
|  | Tentative Track (Input Consoles only) |
|  | Non-NTDS-Reported Air Track |
|  | Ball Tab (1/8" dia.) |
|  | Hook (1/2" dia.) |
|  | Pointer (1/2" dia.) |
|  | Missile Ship Circle and Missile Director Lines (Utilization Console only) |
|  | Marshal Point (Corridor Tab and CAP Station symbols) |
|  | Clutter Point (Reference Point & Tentative Track Symbols) (Input Consoles only) |
|  | Air Hostile, Raid size = Unknown or One |
|  | Air Hostile, Raid size = Few |

| SYMBOL | MEANING |
|---|---|
|  | Air Hostile, Raid size = Many |
|  | Air Hostile, Assigned to Interceptor |
|  | Air Hostile, Engaged by Interceptor |
|  | Air Hostile, Assigned to Missiles |
|  | Air Hostile, Assigned to Missiles and/Director Assigned (FCS number flashing and moving from Air Ready position near ownship to target coordinates) |
|  | Air Hostile, Assigned to Missiles and Director Locked On (FCS number steady) |
|  | Air Hostile, Assigned to Missiles, Director Locked On, and FCS Ready |
|  | Air Hostile, Assigned to Missiles, Director Locked On, FCS Ready, and Launcher Assigned |
|  | Air Hostile, Assigned to Missiles, FCS Ready, Launcher Assigned, and Salvo in Flight |
|  | Air Hostile, Assigned to Missiles, FCS Ready, Launcher Assigned, Salvo in Flight, and Third Salvo Lockout |
|  | Interceptor |
|  | Assigned Interceptor |
|  | Engaged Interceptor |
|  | Downed Air Friendly |

| SYMBOL | MEANING |
|---|---|
|  | Air Hostile with Velocity Leader Indicating Northeasterly Movement |
|  | PIM (Position and Intended Movement) (Reference Point and Surface Friend symbols) |
|  | Vital Area (Variable Diameter Octagon) (Diameter measured across line termination points) |
|  | Bearing Line Point (located on bearing line approximately 30 miles from originating ship) |
|  | ASROC Water Entry Point |

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